PREPARED FOR
GOLDEN GATE BRIDGE AND HIGHWAY DISTRICT

PRELIMINARY FEASIBILITY REPORT

DOUBLE-DECKING
GOLDEN GATE BRIDGE
SAN FRANCISCO, CALIFORNIA

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TUDOR ENGINEERING COMPANY
CONSULTING ENGINEERS

SAN FRANCISCO
MARCH 1966

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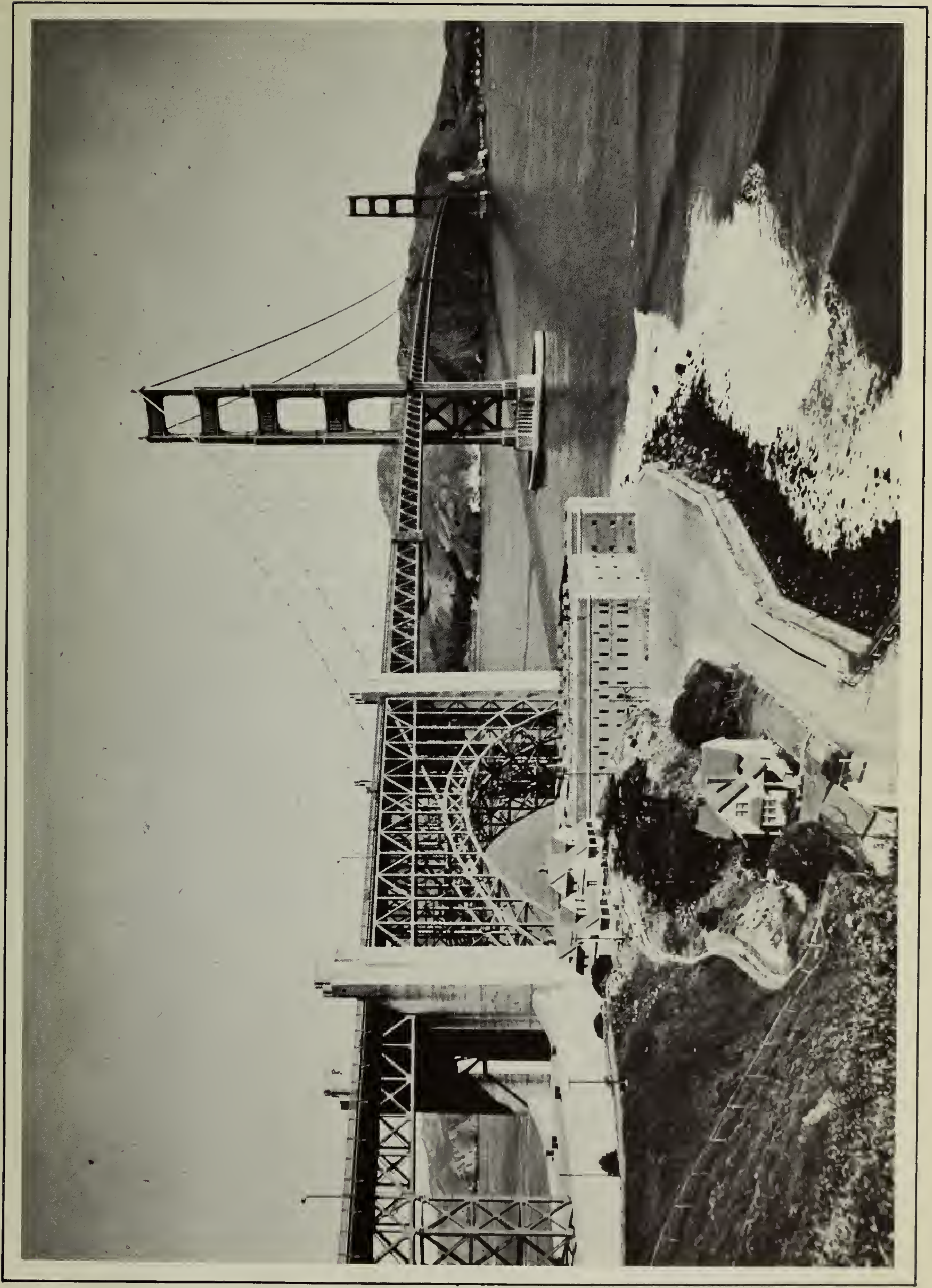

FRONTISPIECE

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CABLE "TENGCO"

Honorable Board of Directors
Golden Gate Bridge and
Highway District
Box 9000, Presidio Station
San Francisco, California

March 15, 1966

Gentlemen:

We are pleased to submit this preliminary feasibility report, in accordance with our agreement of December 21, 1965, pertaining to structural changes, construction procedures and other features of our proposed plan for double decking the Golden Gate Bridge. The plan provides five standard lanes of mixed vehicular traffic on each deck with lower deck sidewalks and suicide barriers.

While in the process of preparing this report in response to the scope of work as set forth in the "General Outline of Features to be Covered in a Feasibility Report on Design and Construction of a Second Deck on the Golden Gate Bridge," dated November 30, 1965, we have reinforced our opinion that the plan is feasible and can be accomplished within safe stress limits with a minimum of interference with vehicular traffic.

We will be pleased to discuss this report in detail with the Board at your convenience.

Respectfully submitted,

TUDOR ENGINEERING COMPANY

Louis W. Riggs

Louis W. Riggs, President

NCRaab

N. C. Raab, Special Consultant

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TABLE OF CONTENTS

Page No.

FRONTISPIECE i

LETTER OF TRANSMITTAL ii

CHAPTER I - INTRODUCTION........................ 1

CHAPTER II - PROJECT DESCRIPTION............... 4

CHAPTER III - DESCRIPTION OF CONTRACTS........ 8

1001 - Park-Presidio Approach.................. 8
1002 - Lincoln Boulevard Separation Structure.............................. 11
1003 - Steel Spans - South Approach............. 12
1004 - Steel Spans - North Approach............. 17
1005 - Marina Approach......................... 17
1006 - North Anchorage - Concrete Work 20
1007 - Lower Roadway - Suspended Span......... 22
1008 - Steel Flooring - Lower Roadway.......... 26
1009 - Steel Work - Towers 27
1010 - Electrical Work......................... 33
1011 - Mechanical Work......................... 35
1012 - Roadway Signing and Striping............ 36
1013 - North Approach - Roadwork............. 37
1014 - Concrete Removal - Upper Deck.......... 37
1015 - Steel Flooring - Upper Deck.............. 38
1016 - Paving - Upper and Lower Decks 40
1017 - Miscellaneous Work...................... 42
1018 - Landscaping............................ 42

CHAPTER IV - TYPES OF BRIDGE DECKING 44

CHAPTER V - BRIDGE DEAD LOADING.............. 49

Table of Contents (continued)

Page No.

CHAPTER VI - DESIGN CONSIDERATIONS.......... 54

- Live Load 54
- Wind....................................... 57
- Earthquake 58
- Deflections 58

CHAPTER VII - BRIDGE TRAFFIC 59

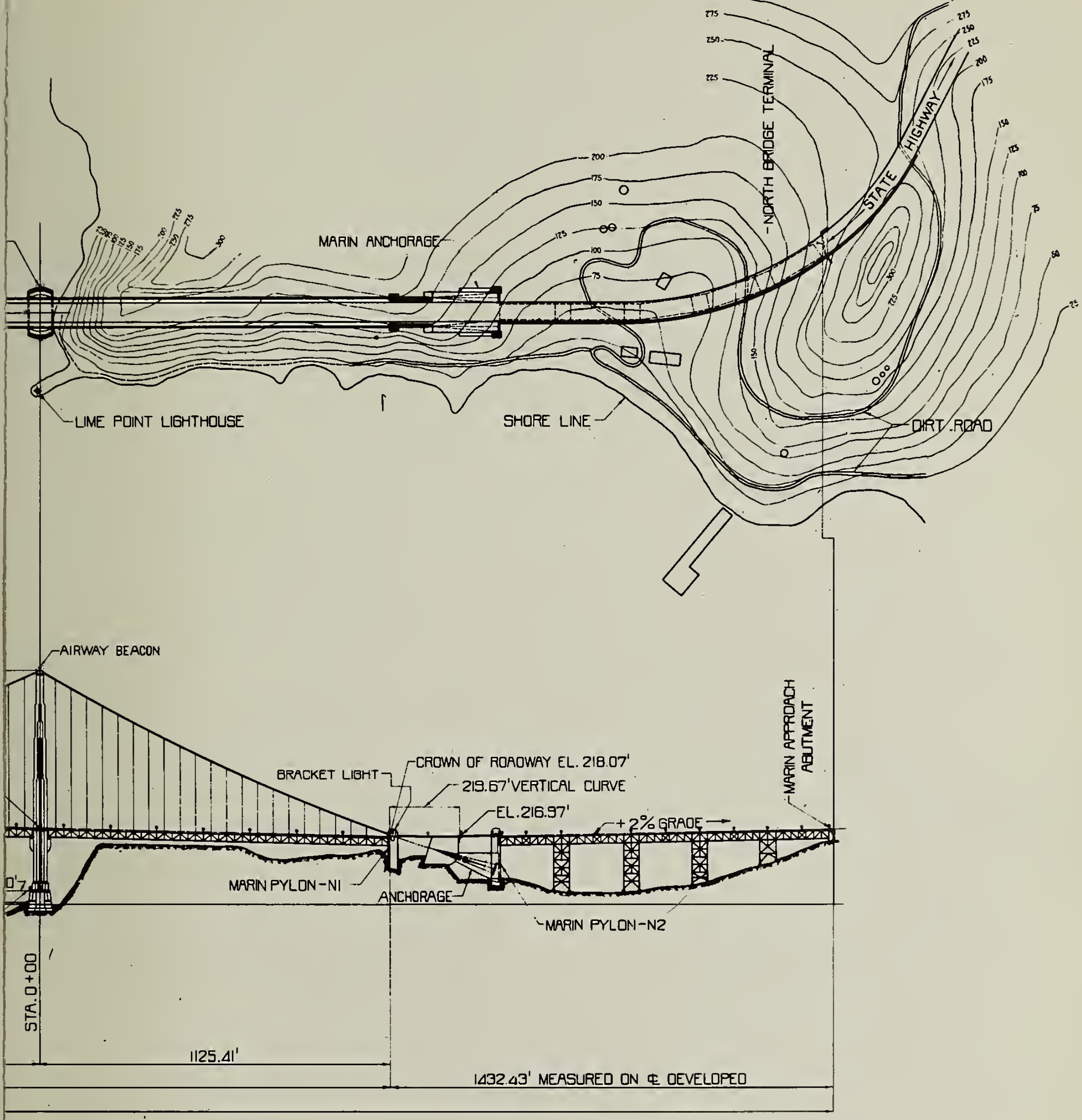
CHAPTER VIII - SUMMARY 72

BIBLIOGRAPHY.................................. 74

GENERAL OUTLINE OF FEATURES TO BE COVERED IN A FEASIBILITY REPORT ON DESIGN AND CONSTRUCTION OF A SECOND DECK ON THE GOLDEN GATE BRIDGE............. 78

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE NO.
	Frontispiece	i
1	Main Bridge - Plan and Elevation	vi
2	Perspective Cross Section - Center Span	3
3	Proposed Bridge Approaches - Connections to Existing Roads	5
4	Park-Presidio Interchange with Golden Gate Freeway	10
5	Proposed Section through Arch Span	13
6	Elevation and Sections - Pylon S1	15
7	Plan and Sections - Pylon S1	16
8	Steel Spans - North Approach	18
9	Proposed Section through Marin Anchorage	21
10	Existing Section of Center Span	23
11	Proposed Section of Center Span	25
12	Tower Elevation - Proposed Revisions	28
13	Tower Elevation at Roadway Level	30
14	Plan of Lower Roadway at Towers	32
15	Floor System - Upper Deck - Three Pass Construction	39
16	Upper Deck - Slab Replacement	41
17	Upper and Lower Deck - Floor Systems	45
18	Upper and Lower Deck - Roadway Pavement	47
19	Comparison of Loadings - One Cable	51
20	Theoretical Bridge Capacity	61
21	Monthly, Daily and Hourly Traffic Counts	64
22	Morning and Evening Traffic Peaks	66
23	Average Annual Rate of Traffic Growth	67
24	Total Monthly Vehicular Traffic - Bay Area Bridges	69
25	Projected Yearly Traffic	71

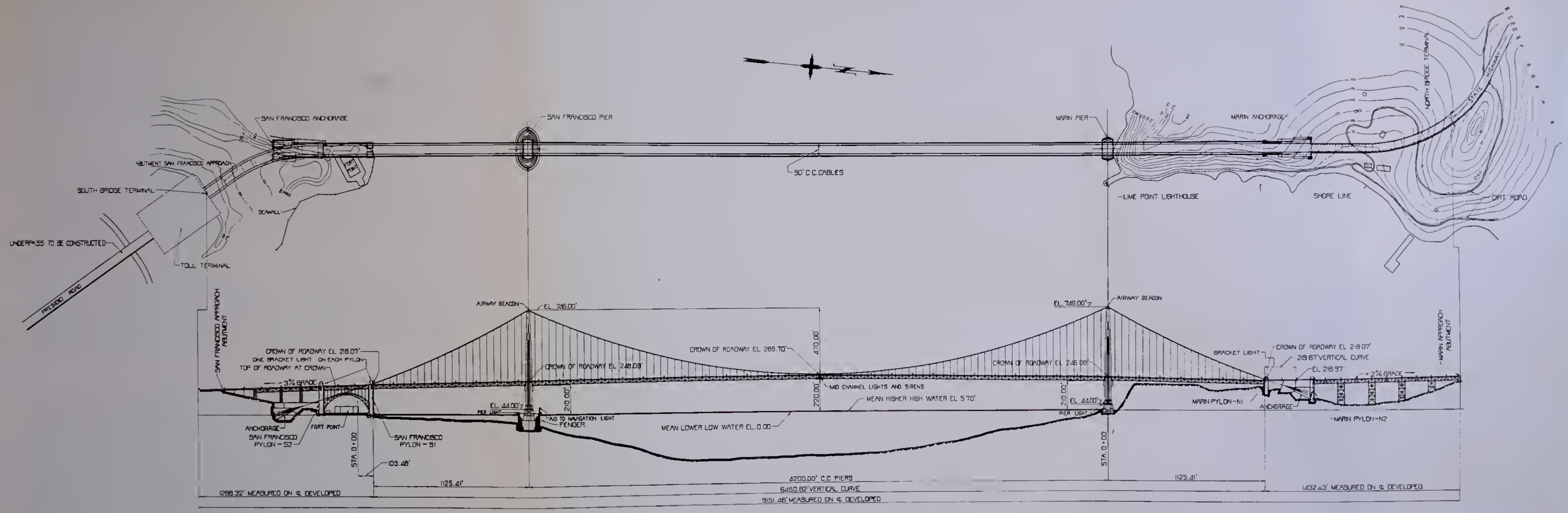


THE GOLDEN GATE BRIDGE
SAN FRANCISCO, CAL.

MAIN BRIDGE
PLAN AND ELEVATION

SCALE IN FEET
100 0 500 1000

FIGURE 1



THE GOLDEN GATE BRIDGE
SAN FRANCISCO, CAL.

MAIN BRIDGE
PLAN AND ELEVATION

SCALE IN FEET

FIGURE I

CHAPTER I

INTRODUCTION

The Golden Gate Bridge and Highway District was incorporated under the provisions of an act of the Legislature of the State of California approved May 25, 1923 to finance and construct a highway toll crossing of San Francisco Bay at the Golden Gate between the counties of Marin and San Francisco (4)*.

The bridge was financed from the sale of a $35,000,000 general obligation, non-callable bond issue due 1972. The bonded debt was an obligation of the counties of Del Norte, Mendocino, Sonoma, Napa, Marin and San Francisco. Vehicular toll revenues have met all debt service requirements since the opening of the bridge.

During the fiscal year 1938, 3,004,268 vehicles used the facility. Traffic has steadily increased during the ensuing period and in 1965, 26,001,203 vehicles crossed the structure. The practical capacity of the bridge has been estimated at 25,000,000 vehicles (15).

Although traffic crossing the bridge has progressively increased, except for the two years 1944 and 1945, there has been a very gradual decline in the average annual rate of growth since the year 1950. This decline could possibly be attributed to the increasing congestion experienced by those in crossing and consequent use of other means of transit or by-passing this route in reaching their destination. If no relief is given, it can be expected that the number of vehicles crossing the bridge will level off within the next few years.

---

*(4) References as listed in the Bibliography.

Two means of relieving the traffic situation have been suggested:

1. Construct another crossing to serve the same areas.

2. Reconstruct the present structure to increase its traffic carrying capacity.

The scope of this report does not include determining the financial feasibility of a new bridge; however, on the basis of vehicular tolls it does not appear possible to construct a new bridge within the next 15 or 20 years, due to excessive cost and the limited traffic potential of the North Bay Counties.

Several reconstruction plans for the bridge have been suggested to increase its traffic carrying capacity during the interim period before construction of a new crossing. One plan proposed a lower level, two-track interurban line for rapid transit (10) (12), and the other recommended the construction of a lower roadway to accommodate four additional vehicular lanes for automobiles only (18). Common to both these plans is the retention of the two-way traffic on the present deck with the absence of any permanent barrier to separate opposing vehicles.

The plan which is presented in this report is based on the concept of making maximum use of the physical capacity of the bridge and providing a traffic facility conforming to freeway standards.

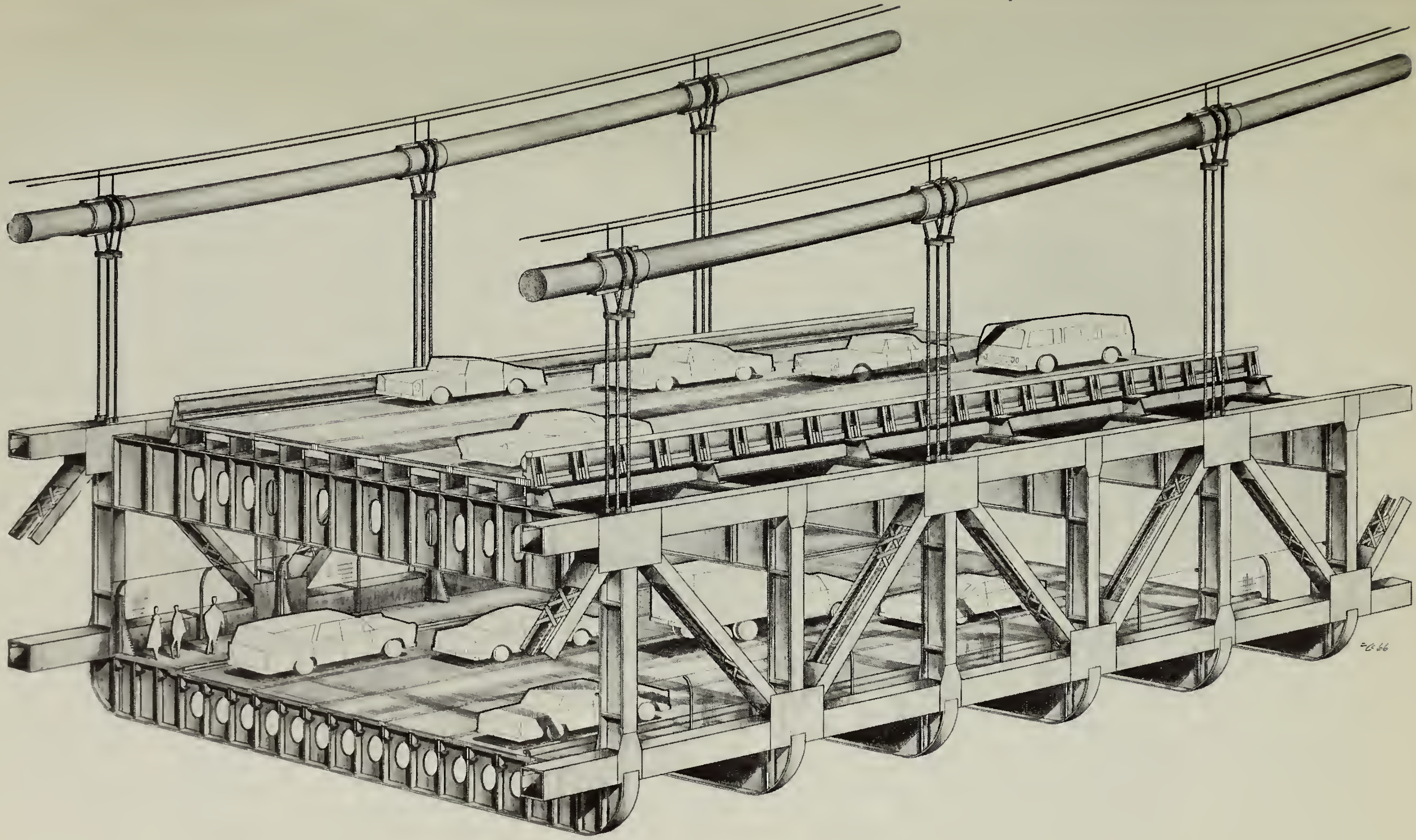


FIGURE 2

PERSPECTIVE CROSS SECTION - CENTER SPAN

CHAPTER II

PROJECT DESCRIPTION

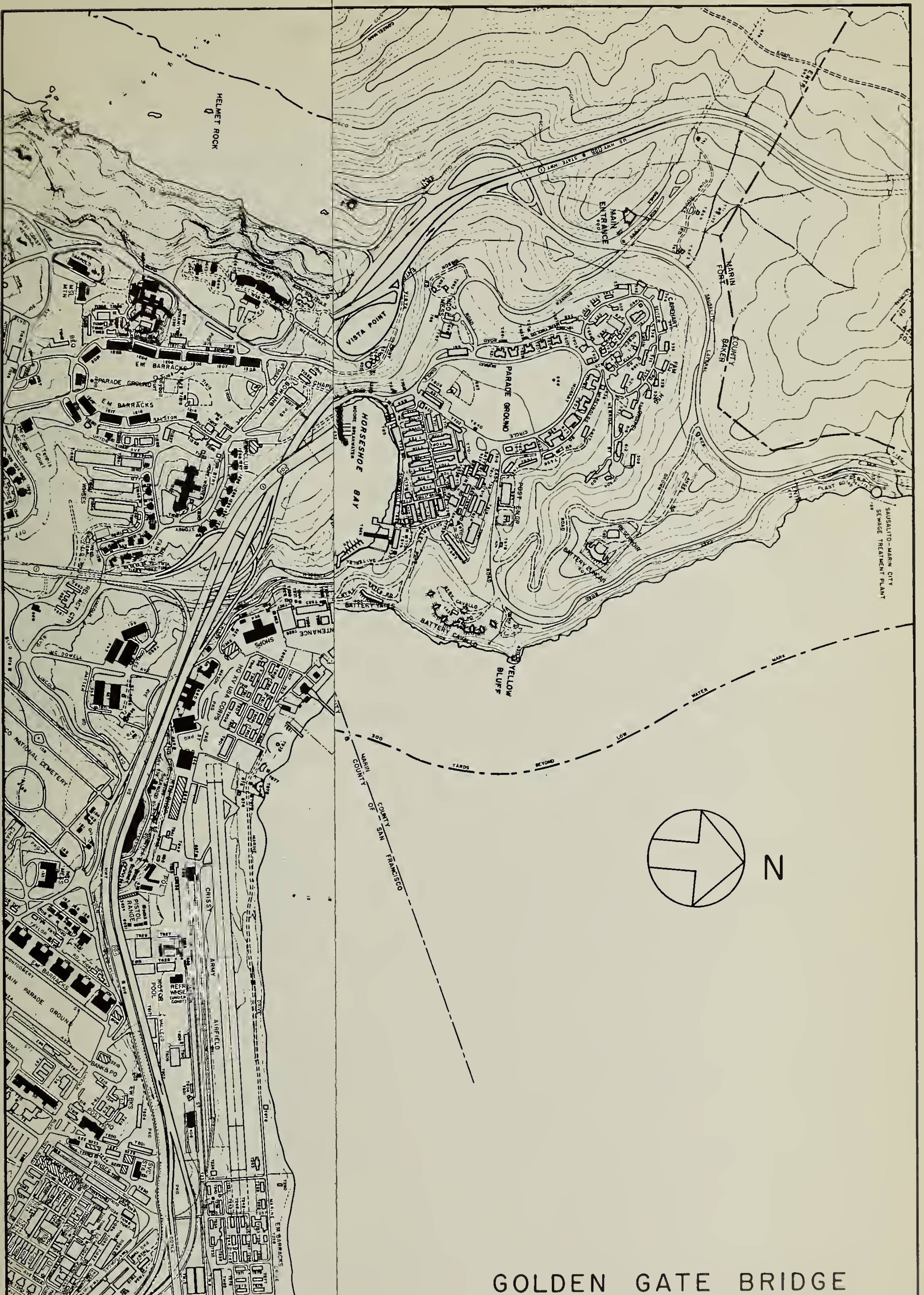
This report describes a proposed plan for the reconstruction of the Golden Gate Bridge and its immediate approaches to fully utilize its maximum traffic carrying potentialities by the addition of a second deck having a 60 foot roadway with sidewalks and suicide barriers on each side. The proposed plan provides for an upper deck roadway carrying five 12 foot lanes of traffic southbound and a lower deck roadway carrying five 12 foot lanes of traffic northbound. It provides for a minimum vertical clearance of 16 feet for the lower deck roadway. With these provisions of adequate lane widths, separation of opposing traffic and adequate vertical and horizontal clearances, the bridge will fit into and become part of any freeway approach systems advanced by State or Municipal agencies (Figure 2).

As will be discussed later in the report, the provisions of the plan can be accomplished without increasing the present weight of the structure and without serious inconvenience to traffic. A general description of the project encompassed by the plan follows.

The plan proposes the construction of a one-way, five lane roadway eventually emanating from the present Marina approach in the vicinity of Lyon Street, and continuing to the Park-Presidio Avenue Interchange where a new southbound ramp leading to Funston Tunnel will be required. From this location, the roadway will proceed to the south abutment of the bridge after passing under the present approach, Doyle Avenue, and Lincoln Boulevard (Figure 3).

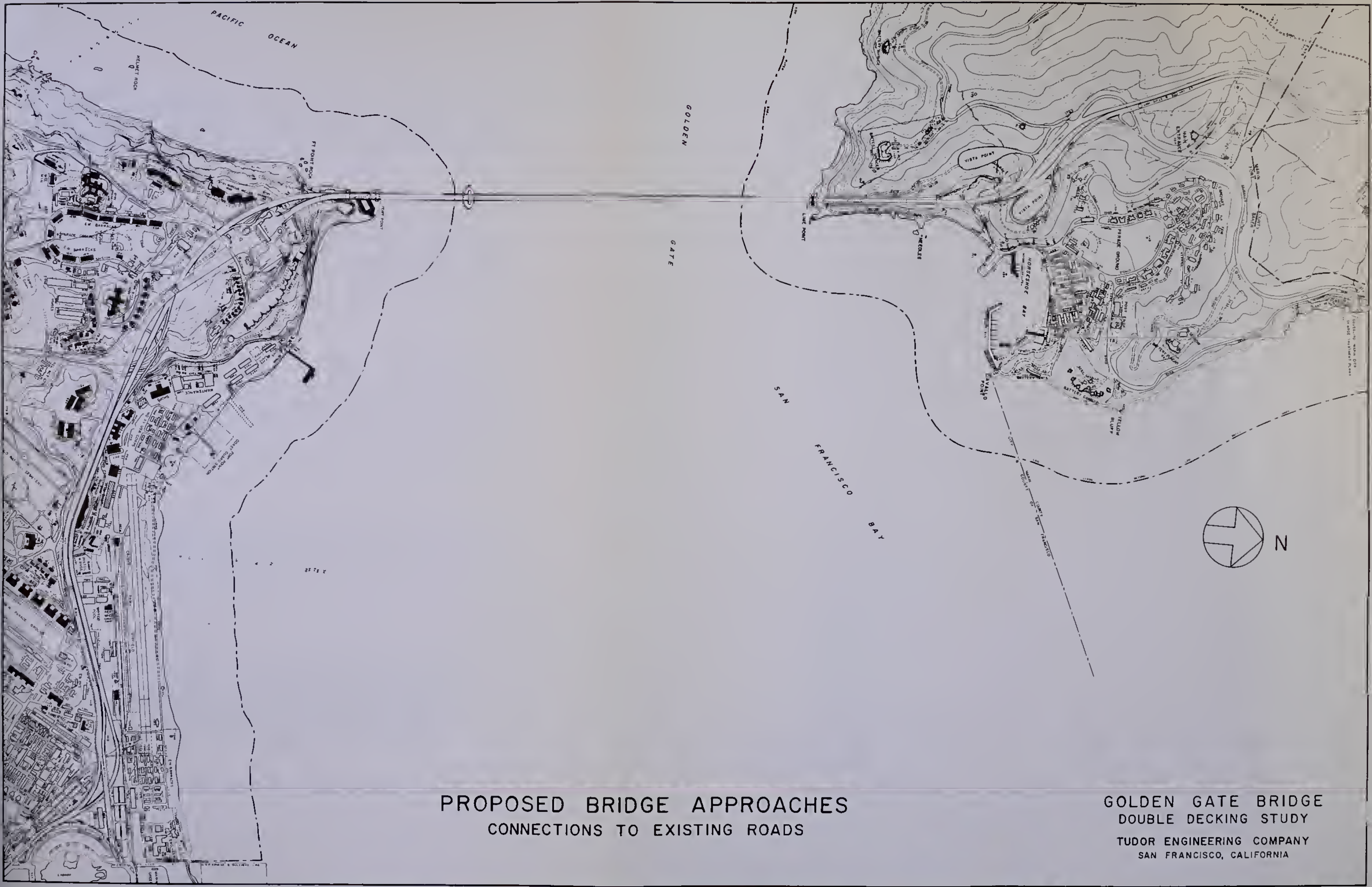
Between the San Francisco abutment and Pylon S2 new steel approach spans, of greater width than the present spans, will be required to accommodate the lower deck five lane roadway.

Between Pylons S2 and S1 the lower deck roadway can be



GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3



PROPOSED BRIDGE APPROACHES

CONNECTIONS TO EXISTING ROADS

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 3

accommodated relatively simply within the framework of the arch span. Pylons S1 and S2 will require extensive alterations including the post tensioning of some of the old structural members and the addition of new beams, walls, ceilings and roadways.

The erection and framing of the lower level floor system through the main crossing will require careful planning and scheduling of working procedures which involve the simultaneous removal of the present sidewalks and wind bracing in connection with the erection of the new steel framing. There will be no unbalancing or overstressing of the structure at any time and provisions would be made for the wind forces as the work progressed across the bridge (Figures 10 and 11).

Pylon N1 and N2 will require alterations similar in nature to those at Pylons S1 and S2. The north anchorage block will not be disturbed except for the reframing of the four inner columns supporting the upper roadway and the strengthening and post stressing of some beams supporting the upper roadway (Figure 9). This work will be carried on simultaneously with the construction of the new lower level roadway.

New steel approach spans will be required for the north approach with the lower deck emerging from under the present roadway and terminating on a newly constructed concrete abutment (Figure 8). The northbound roadway from this point will continue until it intersects with State Highway Route 101 near the Sausalito lateral.

All construction for the five lane northbound roadway can be completed with little or no interference with traffic. Contractors will use the new San Francisco approach for their operations. The materials for the crossing will be delivered over this newly constructed road and probably the longer, heavier members raised from lighters anchored below.

On completion of the new lower deck and after connections

are made at both ends to the existing bridge approach roads, one-way northbound traffic will be diverted to the lower deck of the bridge while the upper level will operate for all southbound travel. Once established, this will be the pattern of traffic movement throughout the remainder of the construction period and upon completion of the project (Figure 3).

The second phase of the reconstruction plan will be the removal of the present seven inch reinforced concrete pavement slab from the upper deck, and replacing it with a paved steel deck (Figure 16).

At all times during the removal and replacement of the upper deck pavement, eight lanes will remain open for bridge traffic. with four lanes of one-way traffic on each roadway. The redecking will be accomplished in three complete continuous passes across the bridge, each pass consisting of the following steps:

1. Removing the upper deck slab.
2. Replacing with a steel grid floor.
3. Filling the grid openings with concrete on both the upper and lower roadways (Figure 15).

The construction period required to complete the outlined plan from the time of awarding the first contract is conservatively estimated as approximately four years.

There are many improvements and betterments that could be included during the construction period to provide for a safer and more efficiently maintained and operated bridge. These improvements could include modern highway lighting, signals, signing and lane markings to add to the safety of the patrons, together with the installation of water, air, power and telephone lines for a more efficient bridge maintenance, and new toll collection equipment and automatic supervisory control for better bridge operation.

CHAPTER III

DESCRIPTION OF CONTRACTS

The Table of Contents has listed in numerical order the number of contracts required for the reconstruction and the designation of the type of work to be performed under each. It would be in the best interest of the project to have the contracts awarded in the order given; however, during the planning and design stages various problems may arise that will necessitate changes in the scheduling. During the construction period there also may be cause for more changes.

Contracts for large construction projects are generally prepared for the various classes of work to be performed and are awarded at appropriate scheduled times. This arrangement permits control and scheduling of the work by the engineer and owner and affords a simple means of effecting changes or alterations desired by the management during the course of construction.

Some contracts such as Highway Signing and Striping, Electrical and Mechanical Work should be awarded during the early stages of the reconstruction. These are needed for the regulation of traffic during the construction period and on completion of the project. Many of the contracts as listed would be combined with others to simplify and expedite the progress of the work. They have been separated at this time for convenience in pricing the different kinds, grades and amounts of materiel needed for the reconstruction. The contracts would include the following work:

1001 - Park-Presidio Approach

The present San Francisco approach to the Golden Gate Bridge is, for the most part, an undivided roadway of six lanes for two-way travel. Access to and from the Golden Gate approach can be made via the Marina Boulevard, Richardson

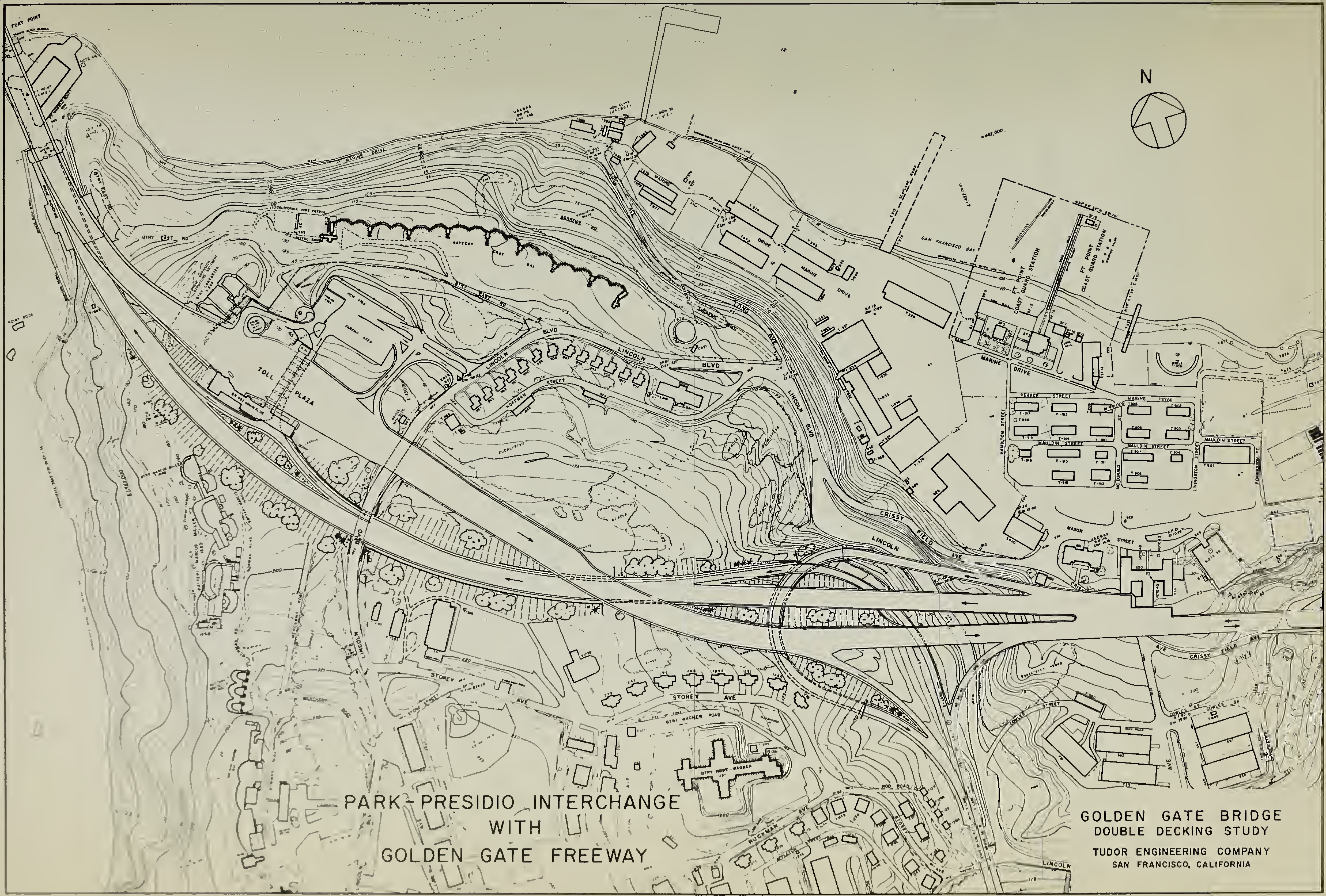
Avenue and Park-Presidio Boulevard in San Francisco. Freeway connections to this approach via the Marina or Park-Presidio Boulevards, or possibly both, have been considered by the Division of Highways in the planning for the new Golden Gate Freeway leading to the bridge.

The new bridge approach should have a minimum of ten lanes, five in each direction, with acceleration and deceleration lanes for all ramp connections. The connections from the bridge and from the Marina to Park-Presidio Boulevard will be retained (Figure 4).

In order that there will be no interference with the present traffic using these approaches to the San Francisco streets and the Golden Gate Bridge, it is deemed advisable to construct first the five lane northbound freeway approach from the Park-Presidio Boulevard intersection to the lower level of the bridge. This roadway will initially provide access to the lower deck for the transportation of men, material and equipment to the work areas, for the storage of materials and the parking of workmen's cars.

The new northbound freeway will have a five lane, 60 foot roadway with 10 foot shoulders, concrete gutters and landscaped side slopes. It will pass under the present bridge approach and Lincoln Boulevard and then descend to meet the proposed lower deck at Pylon S2. All grades for the new northbound freeway are under three percent and the minimum radius of horizontal curvature is 2000 feet (Figure 4).

The depressed northbound roadway, in the vicinity of the toll plaza, will require the removal of the west parking area and all buildings housing the shop and other facilities. These should be relocated in the east parking lot. The administration building, toll plaza and Round House Restaurant will not be disturbed. The present acceleration and deceleration lanes connecting with the toll plaza will be retained.



PARK-PRESIDIO INTERCHANGE
WITH
GOLDEN GATE FREEWAY

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 4

It is proposed to have all activities in connection with the bridge's maintenance, operation and parking to be concentrated in an enlarged area east of the toll plaza.

1002 - Lincoln Boulevard Separation Structure

Both Contracts 1001 and 1002 are part of the same construction that is required to complete the northbound freeway leading to the lower deck and would probably be awarded as one prior to the start of work.

The work to be performed will consist of constructing a five lane vehicular structure under the present bridge approach and Lincoln Boulevard, alterations to the toll plaza tunnel and rearrangement of various road connections.

The toll plaza subway will be used as a pedestrian entrance to the administration building from the east parking area and as a vehicular entrance and exit for the northbound roadway to this area. As this subway will be extensively used as a means of returning to the bridge by the personnel patrolling and maintaining the structure, the interior of the tunnel should be enlarged by the replacing of the pipes and wires suspended from the ceiling into the space originally provided for this purpose and the removal of the truck scale pits that are no longer used. The subway should be brightened by the installation of two continuous rows of fluorescent tubes and painting the interior.

The planning for this area has assumed that one-way toll collection will be substituted, using the present facility for the southbound traffic in its present location. If a lower toll plaza for northbound traffic were to be established, it would have to be placed north of the present subway to collect from those using this means of proceeding to the bridge. The location would have the disadvantage of a short funneling distance from the 15 to 16 toll booths to the five-laned lower deck (Figure 4).

Based on the study made pertaining to any losses in revenue that could result from one-way toll collection and the legal opinion as to the validity of its adoption (16), this report recommends its installation. It will simplify both the physical and mechanical setup for this operation and it appears there will be little, if any, financial losses due to the preponderance of southbound traffic for which tolls would be collected.

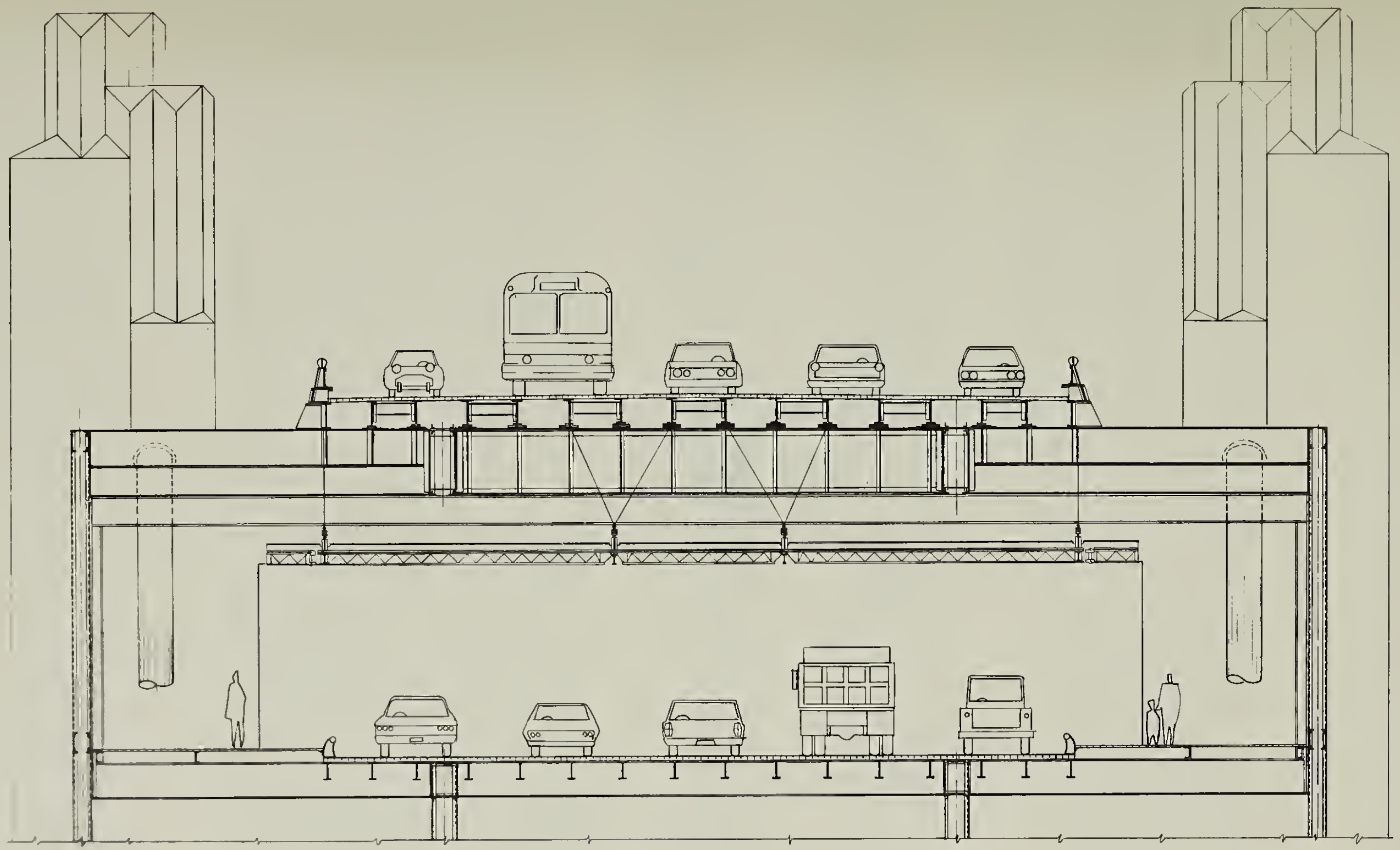
1003 - Steel Spans - South Approach

There will be two distinct operations under this contract. One will involve the construction of a new steel bridge replacing the present three span steel viaduct which ends at Pylon S2. The other work pertains to the reframing of part of the steel truss structure and columns supporting the upper roadway over the arch between Pylons S1 and S2 (Figure 5).

This work can be completed without interruption to present traffic movement and possibly without knowledge of those using the crossing. The two existing sidewalks will be removed as the work progresses.

The original planning for the crossing had never contemplated a second or lower deck. Consequently the trusses in the three span structure which were spaced on 50 foot centers will interfere with the 60 foot roadway for the lower level.

It is proposed to construct a new three span bridge with trusses and piers on both sides of the existing structure (Figure 1). The new lower floor system will be erected and used as a platform to support the present steel trusses while they are being dismantled. Prior to the removal of the top chords in each panel of the existing structure, the new upper floor beam will be placed and wedged under the existing upper deck stringers. The ends of the stringers will have an expansion connection to provide for any movement in the concrete slab.



PROPOSED SECTION THROUGH ARCH SPAN

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 5

All dismantled steel will be used in the Marina approach viaduct, Contract 1005, providing this can be economically accomplished.

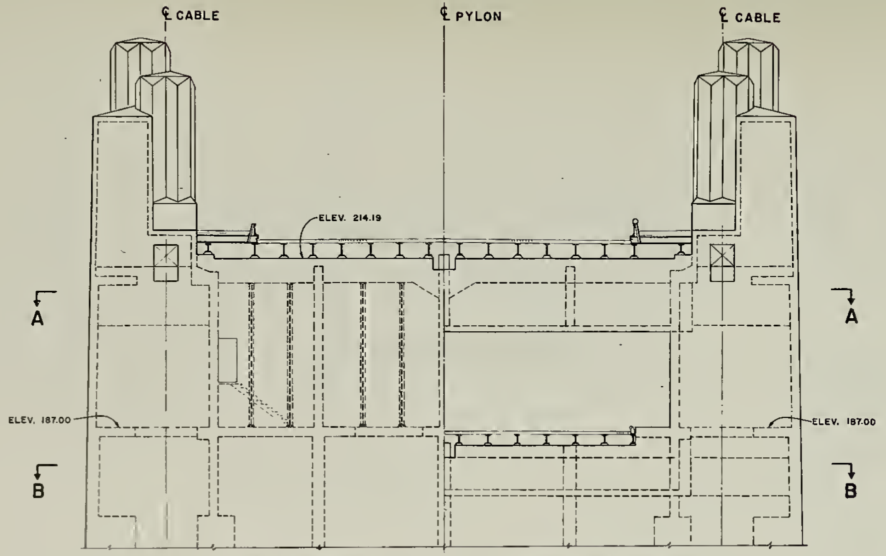
The work to be completed over the arch span requires the removal of the two existing sidewalks, the framing of the lower level floor system, the strengthening of the upper level floor beams to span the 102'-6" between the outer columns, the reframing of the latter, the removal of the two center columns which supported the upper floor beams and, finally, the placing of the lower roadway grid.

To stabilize the arch superstructure during the reconstruction and on completion, it is proposed to have sliding, lateral wind bracing connections to Pylons S1 and S2.

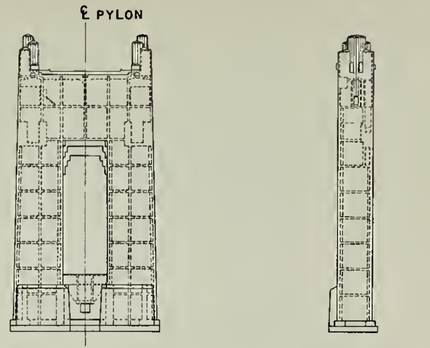
The upper roadway slab will be removed and replaced with a lightweight deck during the regular paving operation for the main crossing.

During the reconstruction of the approach spans, Pylons S1 and S2 will have to be remodeled to accommodate the new lower roadway and sidewalks. The first operation would be the construction of a "U" shaped, post tensioned concrete strut below the upper deck. The legs of the "U", replacing the walls, would reinforce the concrete beams supporting the upper roadway stringers and expansion assembly for the lateral wind forces. The struts will transmit these reactions to the upper legs of the pylons. Additional vertical post tensioned rods will then transfer the stresses into the main shafts of the pylons (Figures 6 and 7).

New assemblies for the roadway expansion and the lateral wind forces will be constructed under the lower deck. The front and back walls between the upper and lower roadway areas will then be removed.



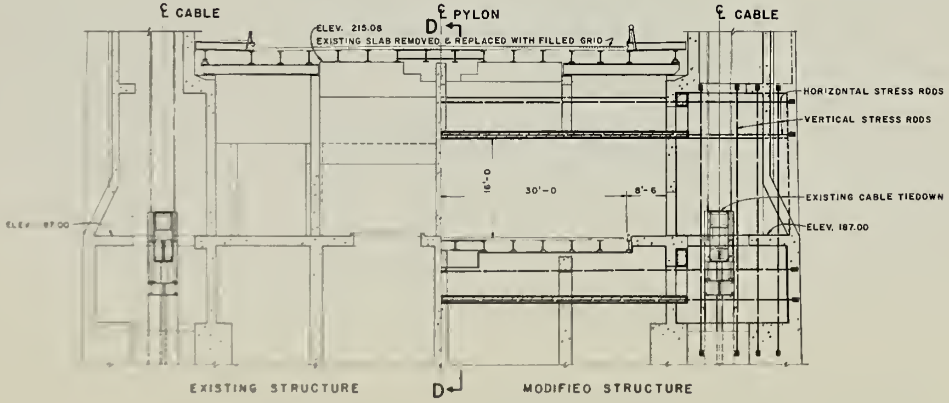
SOUTH ELEVATION AT ROADWAY LEVEL



SOUTH ELEVATION

EAST ELEVATION

PYLON-SI



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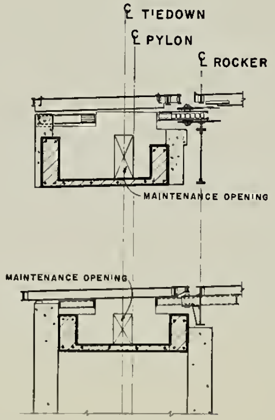

SECTION D

ELEVATION AND SECTIONS PYLON-SI

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

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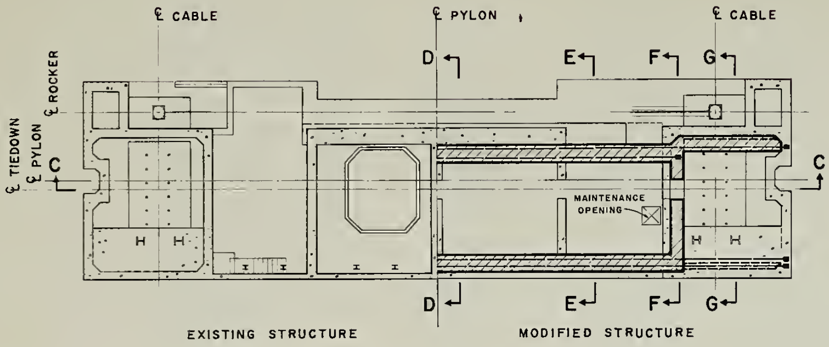
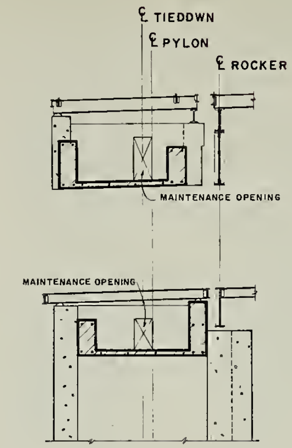
FIGURE 6



PLAN-SECTION A



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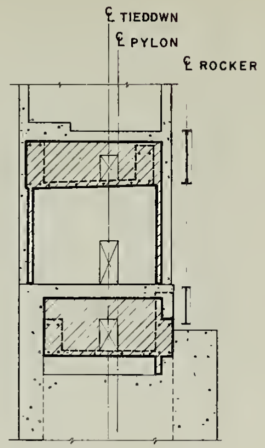
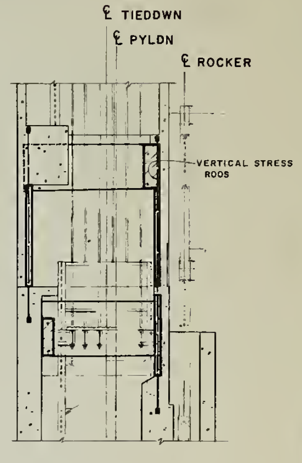
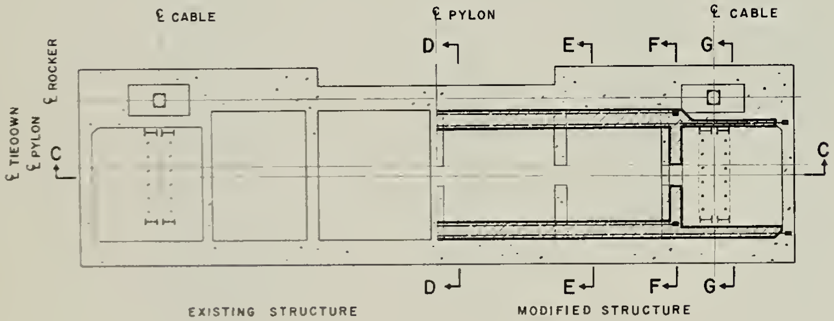


SECTION F



SECTION G



PLAN–SECTION B

PLAN AND SECTIONS PYLON-SI

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 7

The sidewalk space in the pylons will have restricted widths as a result of the new construction required in the upper legs. The two roadway pavements through the pylons will be of the same construction as on the remainder of the bridge.

1004 - Steel Spans - North Approach

The work to be performed under this contract will be similar to that under Contract 1003 - Steel Spans - South Approach and will consist of constructing a new five span bridge with trusses and piers on both sides of the existing structure (Figure 1). The lower floor system will be erected and used as a platform to support the present steel trusses as they are being dismantled. This work should proceed from the Marin Anchorage northward as each of the upper level floor beams are placed to support the stringers of the existing roadway (Figure 8).

All dismantled steel will be used in the Marina approach viaduct to be constructed under Contract 1005, providing this can be economically accomplished.

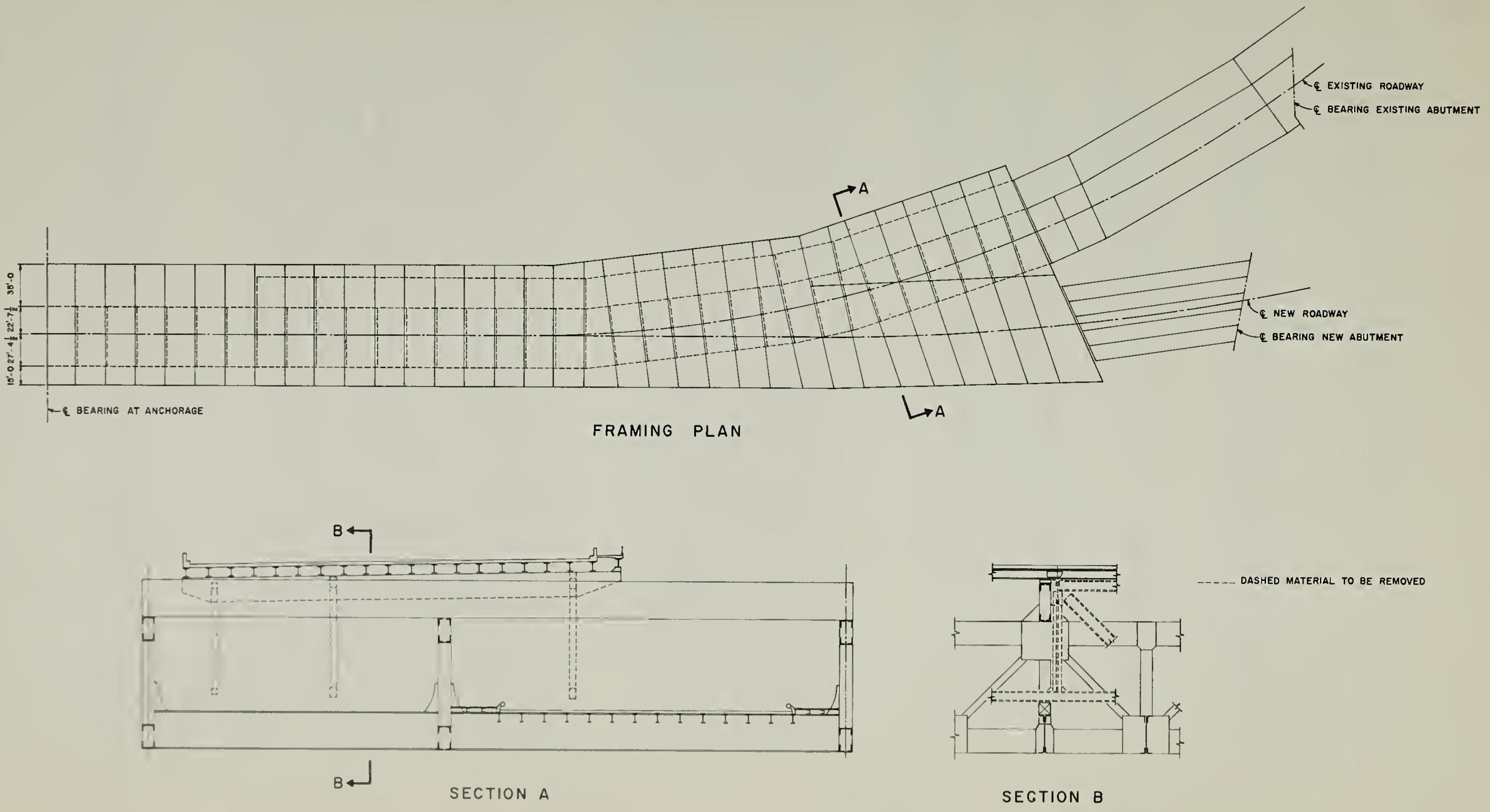
The following contracts are interrelated in the planning and scheduling of the approach work on both ends of the main crossing and should be let as one contract:

Contract 1003 - Steel Spans - South Approach
Contract 1004 - Steel Spans - North Approach
Contract 1005 - Marina Approach

Pylons N1 and N2 would be reconstructed similar to S1 and S2 described in Contract 1003.

1005 - Marina Approach

This contract will require the construction of a five lane steel viaduct parallel to and north of the present Marina approach to route northbound traffic to the lower deck of the bridge.



STEEL SPANS NORTH APPROACH

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FIGURE 8

Also included is an elevated ramp connection for southbound Park-Presidio traffic.

There appear to be three possible ways of extending the present Lombard-Richardson Avenue ramp to meet the new bridge approach:

1. Detour all bridge traffic from Lombard Street north to Marina Boulevard.

2. Construct a temporary timber ramp to the partially completed new northbound freeway.

3. Use the present ramp with a left lane connection to the northbound freeway.

Detouring to Marina Boulevard, all northbound bridge traffic that presently uses the Lombard-Richardson entrance would be the simplest means of handling vehicles during the construction of the new freeway. Since Marina is heavily traveled at present, it would force more commuters to use the Park-Presidio entrance to the bridge. There would be serious delays in the evening peaks; whereas, the morning flow should not be affected.

The temporary timber ramp connection would probably be the most satisfactory means of accomplishing the changeover from the present westbound three lane roadway to the new five lane freeway. The new freeway starting at the Marina would rise at a steeper grade than the present and then pass over the Lombard-Richardson ramp. A temporary timber crossover would then connect the new section of freeway with the present. Traffic would be routed over this section until construction of the new freeway was completed, and both the Lombard-Richardson Avenue and the Park-Presidio ramps connected to it.

A left-hand connection of the Lombard-Richardson ramp to the new northbound leg of the freeway could be accomplished

with a minimum of interference to traffic. If this plan were adopted, the off ramp to Park-Presidio Boulevard should be on the left side. The two left-hand connections would minimize the weaving in this short section of the freeway; however, this construction would be contrary to freeway standards.

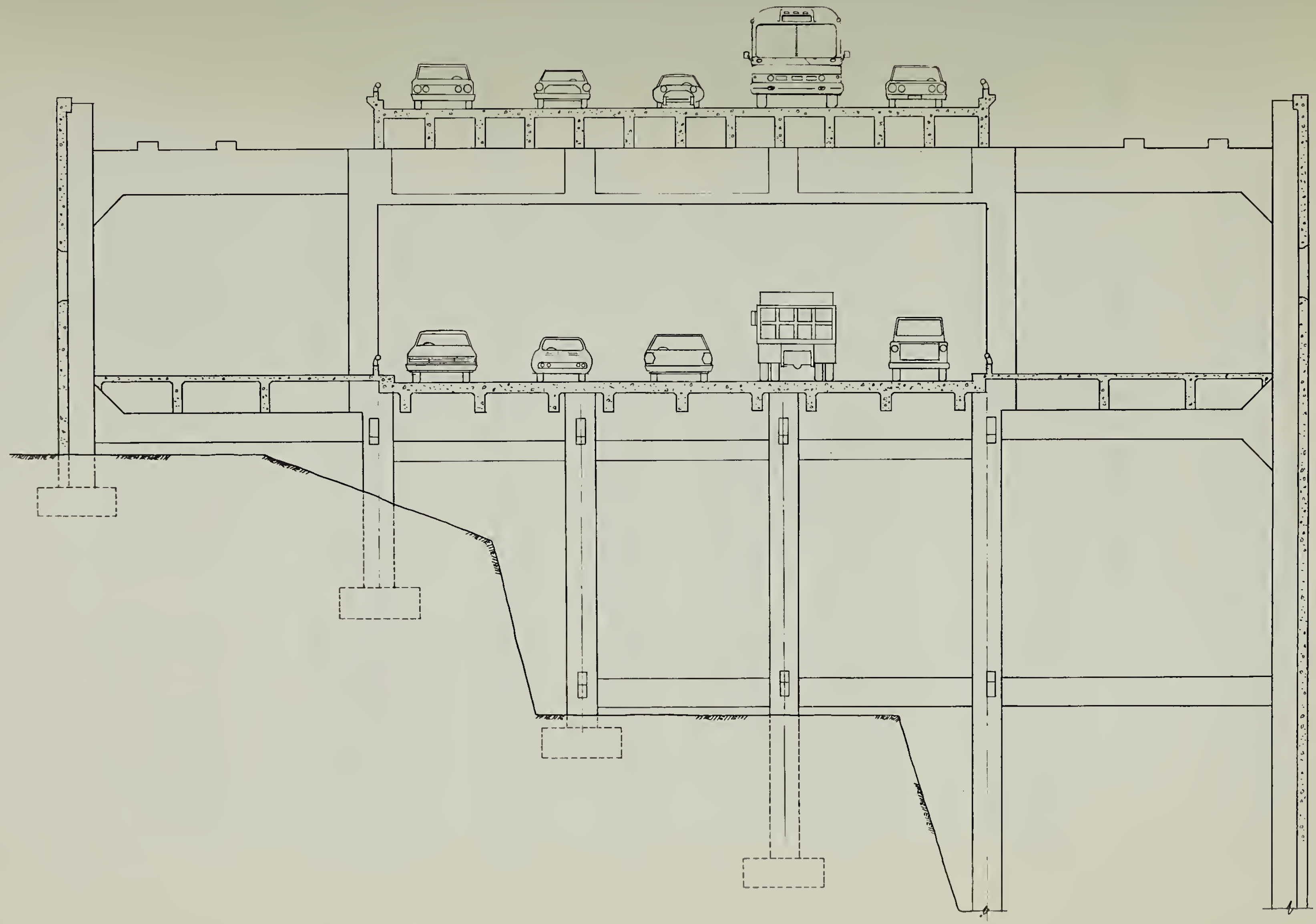
The location of the new freeway connection with the Golden Gate Bridge approach has not been decided upon at the release of this report. There is also a question as to the source of funds for the construction of this northbound leg of the freeway and the agency responsible for its undertaking. The proposed bridge approaches as shown on Figure 4 will provide for all traffic movements to the City streets and as , freeway connections can be made with no interference to the present flow of traffic.

1006 - North Anchorage - Concrete Work

The superstructure of the Marin anchorage is a reinforced concrete cellular structure having six columns supporting the upper deck roadway and sidewalks. The outer row of columns is framed into the concrete wall on each side of the rectangular box structure (Figure 9).

The work required will be the removal of the two sidewalks to relieve the footings of some of their dead load, followed by the construction of the lower roadway which will be supported by the four inner columns. The transverse upper deck floorbeam will be strengthened by the addition of concrete and post stressing. On completion of all the upper deck stressing, the two inner columns between the two decks will be removed, thereby providing a clear 60-foot lower roadway.

There is sufficient space between the two outer rows of columns for the construction of the sidewalks and vehicular refuge bays. It would require a minimum amount of reframing of the structural work to accommodate the latter.



PROPOSED SECTION THROUGH MARIN ANCHORAGE

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 9

A temporary approach road on the north side of the present bridge will be required for the delivery of materials to Contracts 1004 and 1006, and should be under construction at about the same time.

1007 - Lower Roadway - Suspended Span

The orderly sequence of new construction will have the roadwork on the approaches completed for the transportation of men and materials up to Pylon S1, the start of the overwater crossing of the main suspended structure (Figure 10).

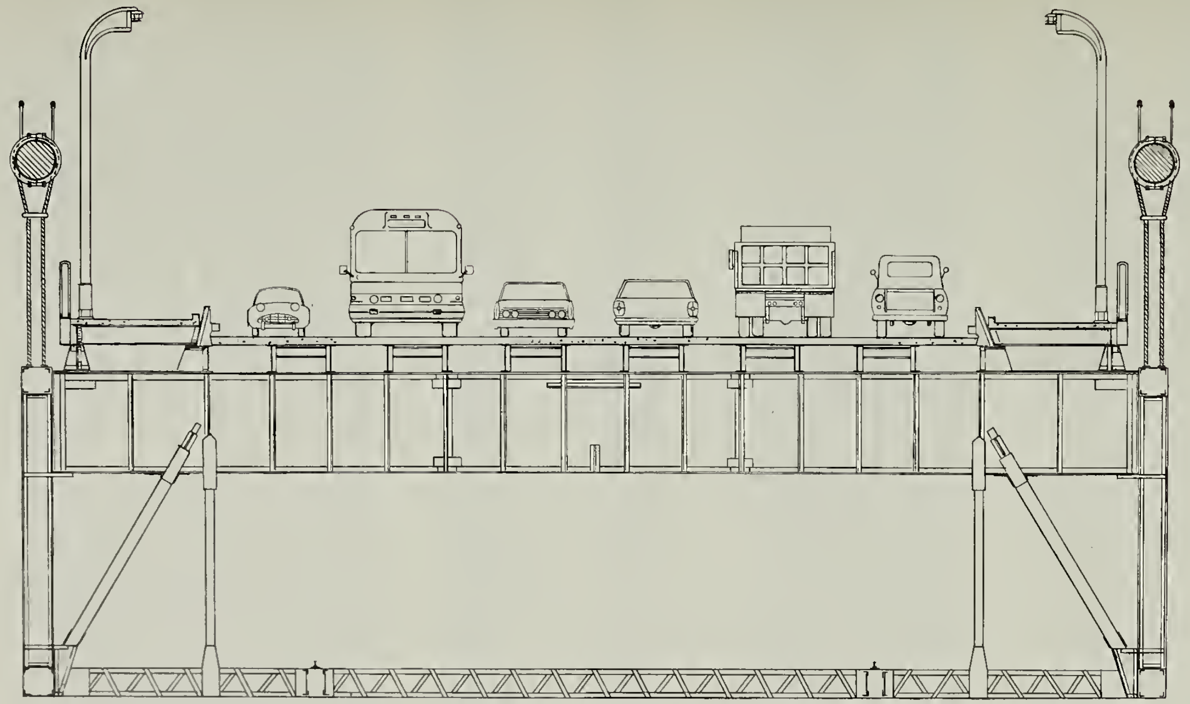
During the construction in the suspended spans, there are three operations that must be carried on simultaneously, all starting from the south end of the bridge, and none of the three progressing ahead of the other two. By so doing, the weight of the new construction will balance the weight of the material removed resulting in no overstressing of any of the bridge members. The procedure would be as follows:

1. Removal of the two pedestrian walks, including the slab, steel framing, handrail, electroliers and whatever utilities are not needed in the bridge operation.

2. Removal of the lower lateral system with the traveling platforms, hangers and knee braces for not more than two panels.

3. Removal of knee brace bracket and opening of a few rivet holes in the lower chord to which would be bolted the prefabricated floorbeam, lifted from a lighter below, followed by the framing of the remainder of the floor system (Figure 11).

The Contractor will be required to install temporary bracing in the opened area to provide for lateral wind forces during the erection of the floor system and new transverse bracing. The open area will be limited to not more than two panels, 50 feet, before the new floor material is placed.



EXISTING SECTION OF CENTER SPAN

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
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FIGURE 10

Bridge patrons would not be affected by and probably would not be aware of work being carried on during the erection of this lower level roadway. It is planned to have the electrical, mechanical and highway signing contracts under way at the same time.

All steel will be removed from the site, providing there is no need for its refabrication and reuse in the structure.

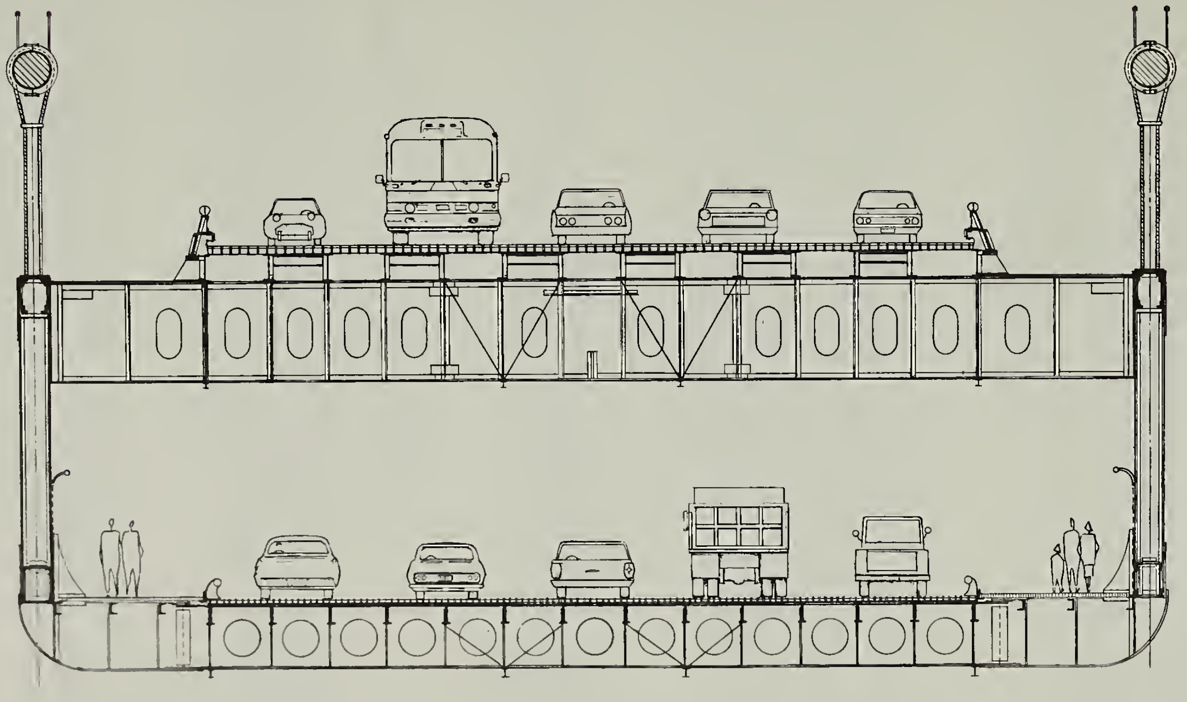
Movable maintenance platforms will be constructed and suspended from tracks supported by the upper and lower floorbeams. The cleaning and painting of all new steel will follow immediately after its erection. Openings will be made through the upper floor beams during this phase of the work for the convenience of moving men and materials (Figure 11).

The erection of the two lower deck sidewalks, suicide barriers and other miscellaneous work would also be included.

A net or similar safety device will be required of the Contractor for all open areas during the progress of the work.

The procedure in erecting the new lower deck floor system will require the removal of one and not more than two panels of the present sidewalks and lower level wind bracing, including all connection plates. The removal of the knee brace riveted connections to the stiffening trusses will provide the bolt holes for the floorbeam braces. The removal of the six lower rivets from the outside gusset plates will provide the holes for the bolting of the lower curved flange plate of the new floorbeam. There will be no additional strengthening required for the lower chord of the stiffening trusses.

After the floorbeam has been raised and connected, the roadway and sidewalk stringers will be erected and bolted to the floorbeams. Next, new transverse bracing will be connected



PROPOSED SECTION OF CENTER SPAN

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
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to the stringers, followed by the maintenance platform tracks. The open grid steel roadway and sidewalk will then be placed.

If the steel for the total floor system is raised off lighters anchored in the water below the particular panel that is being worked on, the lifting lines and materials would foul the safety net under the bridge. Therefore, it would probably be the best plan to have all new steel, except the floorbeams, moved in over the completed deck.

The proposed suicide barrier will be fabricated in sections, two to a panel, having a rectangular wire screen attached to a light metal frame. When maintenance is required, a section can be swung out onto the walkway. The vertical maintenance gantry would be located at the panel where work is to be performed and would be used by workmen in gaining access to the upper and lower traveling platforms.

The open space between the roadway curb and rail of the upper deck and the side of the bridge should discourage suicide attempts.

1008 - Steel Flooring - Lower Roadway

Although this work will, by necessity, be a part of or a subcontract under Contract 1007, it has been separated mainly due to fabrication and placing of the flooring, which is different from that of the other bridge steels.

The flooring is assembled and fabricated to a standard width and to lengths that can be transported and handled. It would be desirable to have the panel span the 60 foot roadway width in one piece.

After placing the grid upon the steel stringers the two units will be drawn together and welded to form a composite

floor system. Since the coefficient of expansion is the same for both grid and stringers, there is no reason for transverse expansion joints in the deck. This will provide a uniform and smooth riding surface, the only breaks occurring at the steel expansion fingers at the ends of the suspended spans.

Along with the grid there will be required a sheet metal strip to retain the lightweight concrete that will be placed to fill the lane section (Figure 16).

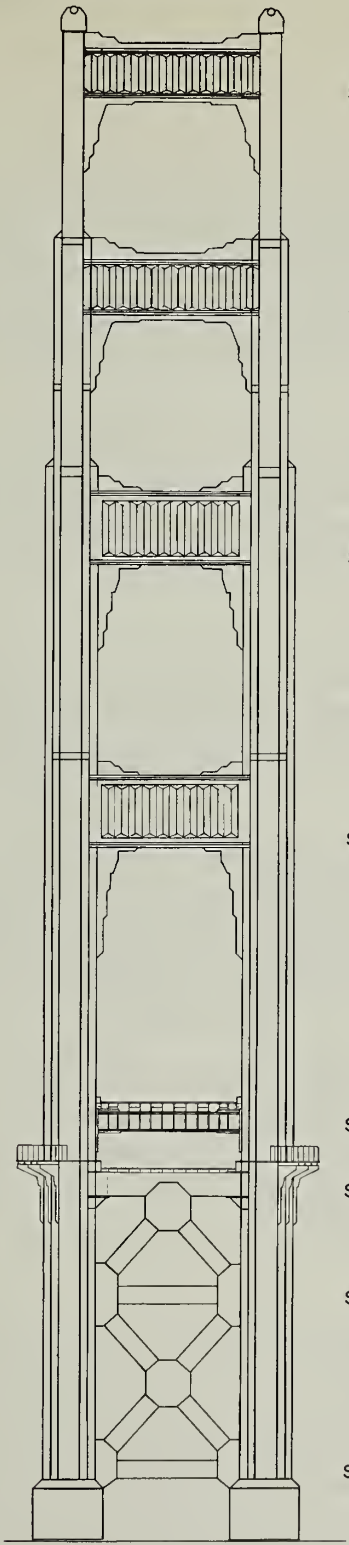
This steel grid would remain open during the construction of the lower deck. This procedure is required to keep the total weight of the suspended structure, including the weight of the new construction, below the present dead load.

The lower lateral wind bracing, including the hangers and knee braces will have to be removed to provide space for the second deck. The new floor framing will include a lateral bracing system. The suspended span wind reactions will be taken into the towers and pylons at both the upper and lower roadway levels through a pin connected sliding wind assembly.

1009 - Steel Work - Towers

The work to be performed under this contract will consist of a revision in the main tower bracing at the lower roadway level, the framing for the lower lateral wind bracing, the construction of the lower roadway and expansion assemblies, the lowering of the two tower sidewalks to the elevation of the new roadway and the strengthening of the two tower legs between the upper and lower roadways (Figure 12).

The two diagonal upper legs of the main tower cross bracing will have to be removed to accommodate the 60-foot lower roadway passing through the tower (Figure 13). The present bracing will be replaced by six roadway floorbeams acting as struts, four of which will be placed in the same vertical plane as the removed cross framing (Figure 14).



TOWER ELEVATION PROPOSED REVISIONS

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 12

The expansion assemblies for the transfer of both wind and vehicular loads from the suspended structures to the main towers will be similar to those which now exist. The suspended span wind reactions will be transferred to the tower legs at both the upper and lower roadway levels.

The tower legs are not tapered in the vicinity of the two roadways; consequently, the present sidewalk can be lowered, without modifications, to the lower elevation and bolted to the tower legs through holes prepared for this move.

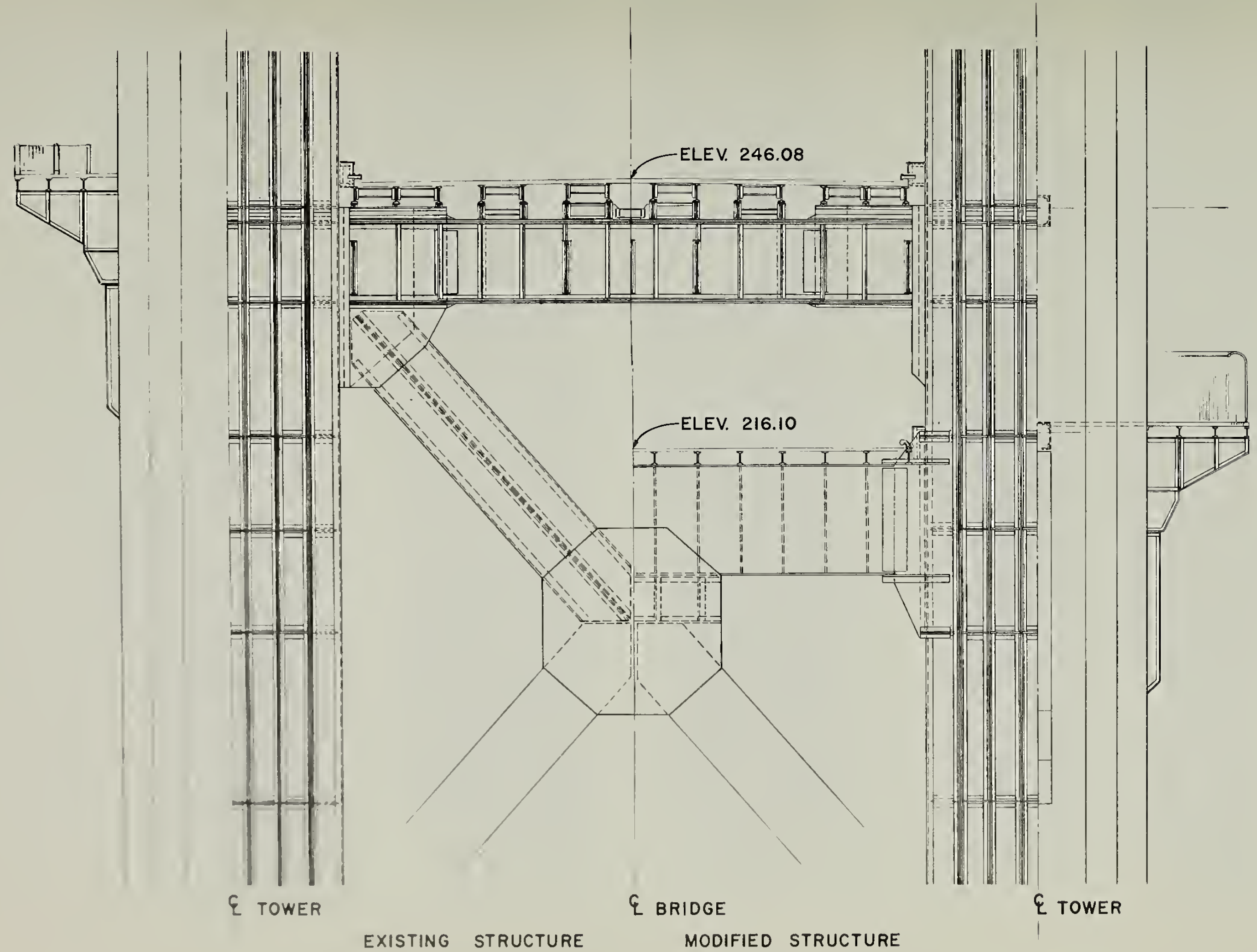
A preliminary study for the tower modification indicates that the two upper members of the tower cross-bracing can be removed without jeopardizing the safety of the tower by the following operations (Figure 13):

1. An analysis of various loading conditions acting upon the structure would first be made to determine if the tower shafts will require additional vertical reinforcing, particularly in the vicinity of the two roadways. If needed, the reinforcing will be added prior to the following steps.

2. The two new outer floor beams with expansion and wind bracing assemblies would be bolted in place (Figure 14). At this stage there will be provided eight struts to transfer the transverse wind reactions into the tower legs, six existing on the upper level and two on the lower. The tower cross-bracing will still be in place.

3. The 128 inch wide face plates covering the three inner cells of the west tower leg facing the roadway will be removed leaving the four vertical cell plates and the three diaphragms between Elevations 195.4 and 217.4 exposed. Double plates will be bolted to the vertical cell steel to act as reinforcing and a connection splice for the four new floor beam struts. The three cell diaphragms will be reinforced and three 41 inch wide face plates bolted in position closing the open cells.

4. The above operation will then be repeated on the four inner cells of the east tower leg facing the roadway.



TOWER ELEVATION AT ROADWAY LEVEL
SECTION A

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
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FIGURE 13

5. The next step will require the removal of two of the four plates in the upper legs of cross-bracing. At this stage of the operation there will be provided eight struts to transfer the transverse wind reaction into the tower legs, six on the upper level and two on the lower. The cross-bracing will have two plates, where Step 3 has four.

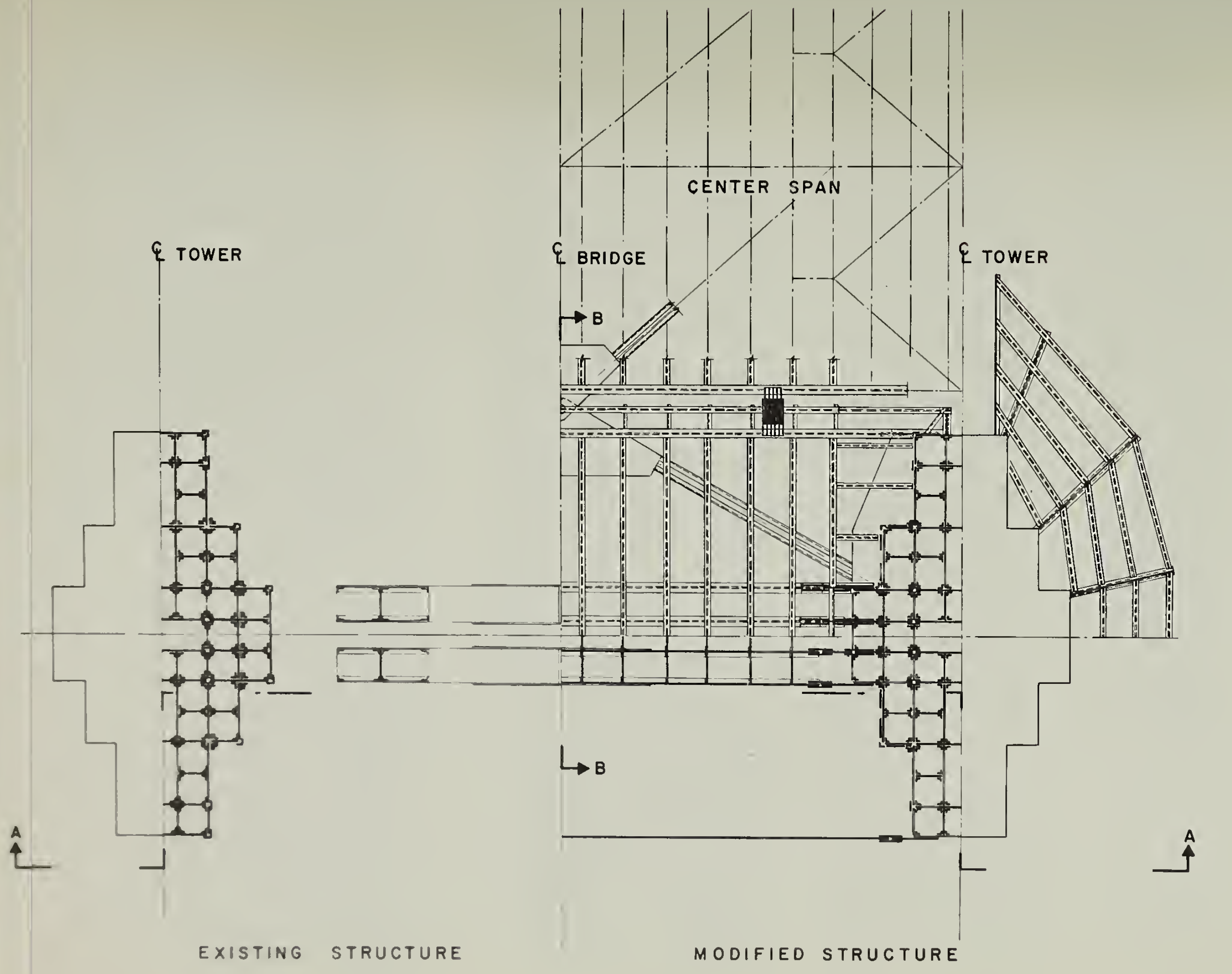
6. Two of the four lower level floorbeam struts will be bolted to the double splice plates described in Step 3 to fill the void left by the two cross-bracing plates removed in Step 5. At this time there will be ten struts in place.

7. The next step will require the removal of the remaining two plates in the upper legs of the cross-bracing and the placing of the last two of the six lower level struts. At this, the final stage, there will be twelve struts in place, six on each roadway level (Figure 13).

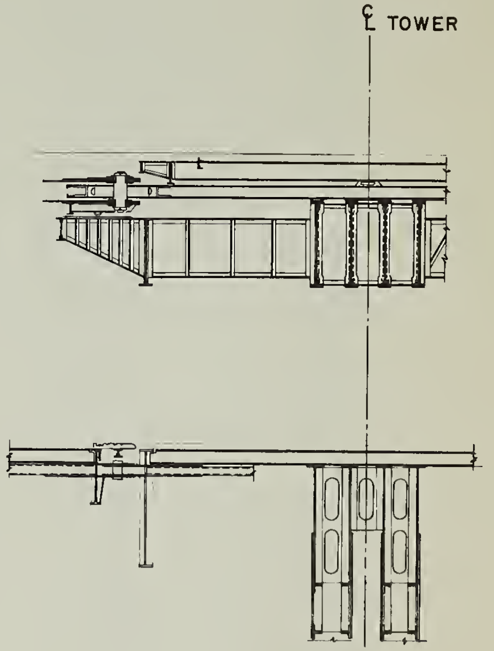
During the entire operation of removing the cross-bracing legs and replacing with the new Strut 5-6 there will be at all times eight struts in place where six previously existed with the cross-bracing. At the start of this changeover the wind reactions to the tower legs will be divided and taken at the upper and lower roadway levels.

The new Strut 5-6 will be similar to Strut 5 consisting of four plate girders framed into the tower legs and all plates in the same vertical plane. The new struts will have plates 144 inches in depth compared to the existing 102 inch plates. All floor beams will have moment connections to the tower shafts.

The pin connected sliding joint for the main span longitudinal wind bracing will require a new support to provide the necessary lower roadway clearance. The tracks for the traveling maintenance platforms will terminate at the ends of the suspended spans as there is insufficient roadway clearance for the platforms to travel through the towers.



PLAN OF LOWER ROADWAY AT TOWER



SECTION B

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
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This contract would probably be combined with Contract 1007 - Lower Roadway - Suspended Span - as work is similar.

1010 - Electrical Work

The extent of the electrical work to be considered under this contract will depend upon the desirability of improving the present maintenance and operating facilities.

This contract should continue throughout the construction period as present operational facilities will have to be maintained and the new work completed prior to the opening of the lower roadway to one-way northbound traffic.

It is necessary to maintain all electrical operational facilities throughout the reconstruction period, such as the roadway lighting, beacons, and clearance markers, which can be accomplished by a temporary hookup to the power source on the Marin end of the bridge. As the work progresses from the south end, the new electrical installation will become effective.

One of the proposed improvements would be the installation of a 12 kv power line across the structure with a hookup to the two main power sources on each side of the Bay. This will require a substation at each end of the bridge with proper switch gear and metering equipment. An automatic switchover at the center of the bridge will supply energy to the entire crossing in the event of power failure at either source. This will lessen the need for the present standby equipment.

A new and more efficient roadway lighting system should be considered for the upper deck. Handrail lighting is becoming a more popular lighting installation for bridges, eliminating glare, providing uniform lighting over the entire roadway area and offering less resistance to wind. Fluorescent tubes of any desired color can be installed. This work would have to progress along with the demolition of the sidewalks on the upper level and the construction of the lower roadway.

The 16 foot clearance between the upper and lower deck will require either a continuous line of lighting on both sides of the roadway and under the floorbeams or alternate spot lighting in each bay of the upper flooring. The lighting fixtures should be above the transverse floorbeams to cut off the view of the lamp from the drivers' eyes. The low mounting height would call for the low intensity fluorescent lighting.

An electrical substation may be required at each main tower for the roadway lighting bank and possible auxiliary booster air compressor for the two main air lines.

For maintenance purposes, there should be installed a three phase 110-220 volt power line with conveniently located outlet box for the use of men working on both the upper and lower traveling platforms.

A telephone line on each side of the two decks with conveniently located call boxes can be installed for the use of both patrons and maintenance personnel. Yellow flashing signals can be located at each call box and so wired to notify approaching traffic of a stalled vehicle ahead. Such warnings expedite the clearing of the lane for an unobstructed approach by an emergency truck.

Platforms, recessed in the railing of the upper roadway, would have the same equipment. Telephones should be located above each other for simpler electrical wiring, and opposite each other to avoid anyone crossing the roadway to place a call.

The installation of an automatic supervisory system would be an asset to the bridge operations. The malfunctioning of any piece of equipment such as beacon, clearance and roadway lights, other electrical and mechanical apparatus and a stalled vehicle will be indicated both audibly and visually on a bridge layout panel in the toll sergeant's office.

If desired, new toll collection equipment could be installed as a part of this contract.

1011 - Mechanical Work

The extent of the mechanical work to be considered under this contract will depend upon the desirability of improving the present maintenance and operating facilities.

This contract would consist mainly of the installation of two four-inch fresh water lines and two four-inch compressed air pipes across the bridge with connections to their sources of supply.

The water line will be connected to the San Francisco water supply at the toll plaza with an electric booster to supply water with sufficient pressure for fire fighting at any location on the bridge. It will also be used in cleaning bridge paint work.

Machinery for the supplying of compressed air with a minimum of 100 psi at any point in the line would be located in the electrical substations at each end of the bridge. Boosters located at the main piers may be required to maintain the required pressure along the lines. The compressors will be automatically started each work day morning by calendar clock and stopped at the end of the working period. The air system will be connected to the automatic supervisory control which can be manually operated by the toll sergeant if necessary.

The compressors would automatically switch on and off during the day as the air pressure in the receiver tanks varied.

Sandblasting operations place the greatest demand on the supply of air; however, compressed air has other uses in the maintenance and operation of the bridge such as required for pneumatic tools, paint spraying and actuating air horns.

The traveling maintenance platforms suspended below the two decks and the vertical platforms outside the trusses should be mechanically operated by air motors. These platforms are generally provided with air and power lines for the attachment of tools used in the maintenance operations. Flexible hoses and cables connect them to the supply lines on the walkway level.

Most grime is removed from the paint work by steam cleaning. Small mobile flash boilers, moving on the walkways, can proceed along with the painting.

As all the maintenance equipment, supplies, ladders and flexible connections are handled from the two walkways, the bridge roadway lanes can remain clear throughout the day.

1012 - Roadway Signing and Striping

A contract can be awarded as soon as work is started on the approaches to the lower deck for the signing and striping of all the roadways leading to, from and across the bridge on both the upper and lower decks.

If the Type D deck (Figure 18) is adopted, the striping for the greater part of the project will be eliminated as the nine inch width of open deck grating separating the eleven foot pavements produces a permanent lane marker. This type of lane designation will have a secondary effect of delineating a stripe across the bridge.

Internally lighted route and warning signs are recommended for installations requiring artificial lighting. All other signs will be the standard porcelainized sheet metal, with standard marking and with some reflectorized lettering.

1013 - North Approach - Road Work

The lower deck northbound roadway will emerge from the east side of the bridge approach spans, pass across part of the Vista Point parking area and then connect to State Highway 101 near the Sausalito lateral. Until some determination has been made by the State Division of Highways as to the routing of the freeway in this vicinity, the exact alignment and grades of the northbound lanes cannot be determined.

Since southbound traffic will be prohibited from crossing the new freeway to reach Vista Point, it would be advisable to develop another parking area at a higher elevation on the west side of the freeway (Figure 3).

The construction to be performed under this contract will be similar to the roadwork of Contract 1001 - Park-Presidio Approach, consequently both should be combined and let as one.

1014 - Concrete Removal - Upper Deck

Prior to the award of this contract, all work connected with the northbound leg of the freeway will be completed and one-way traffic started. The six lanes will remain on the upper deck with the lower level striped for five.

The plan for double decking this structure without increasing any of the present stresses in the cables, trusses and the steel framing for the roadways will require the removal of the present roadway slab and the replacing of it with one of lighter weight (Figure 15).

The removed concrete slabs could, if desired, be utilized around the Marin pier as a protection against tidal currents.

The removal of the slab in each panel will be accomplished by first running a saw cut along the inboard edge of the

first five stringers to the top of the reinforcing steel. The concrete under the curbs will next be broken out to the first saw cut exposing the slab reinforcing. The exposed reinforcing steel will be flame cut along the inboard side of the stringer causing the slab to revolve over the next inner stringer. The cantilevered weight of the slab will open the saw cut exposing the steel. The reinforcing will then be cut and the panel lowered onto a waiting truck below. All broken concrete will be directed into the truck by movable sideboards suspended from the stringers.

After removal of the roadway slab, the open space between the stringers next to the four traffic lanes in use will be closed by multiples of short wooden barricades (Figure 16). The barriers are slid along the tops of the stringers as the present pavement is removed. The same type of barricade will be used on the lower level to guide the five lanes of traffic into four lanes paralleling the working area.

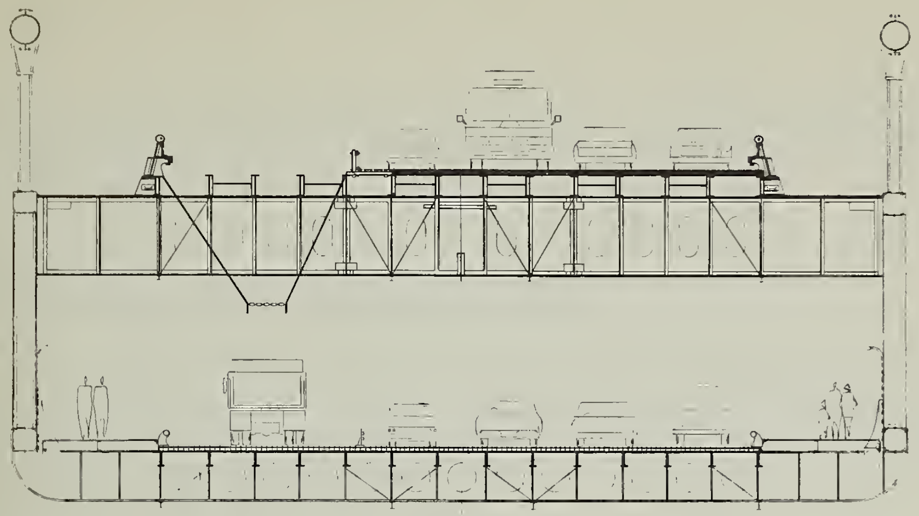
The means of barricading the roadway to provide four full lanes of traffic on both the upper and lower decks around the working area for the three continuous construction operations of deck removal is shown on Figure 15.

1015 - Steel Flooring - Upper Deck

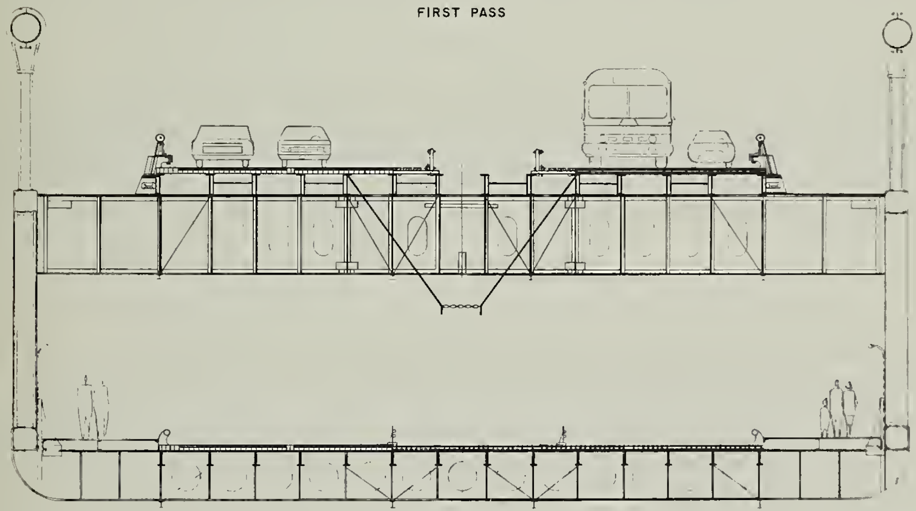
This contract will by necessity have to be awarded at the same time as Contract 1014 and should be performed by the same contractor, as work would have to progress simultaneously with the slab removal.

The steel grid floor will be laid and welded to the tops of the present stringers after cleaning the upper flanges. This operation will require the drawing of the grating into contact with the stringer before welding the two units into a composite floor.

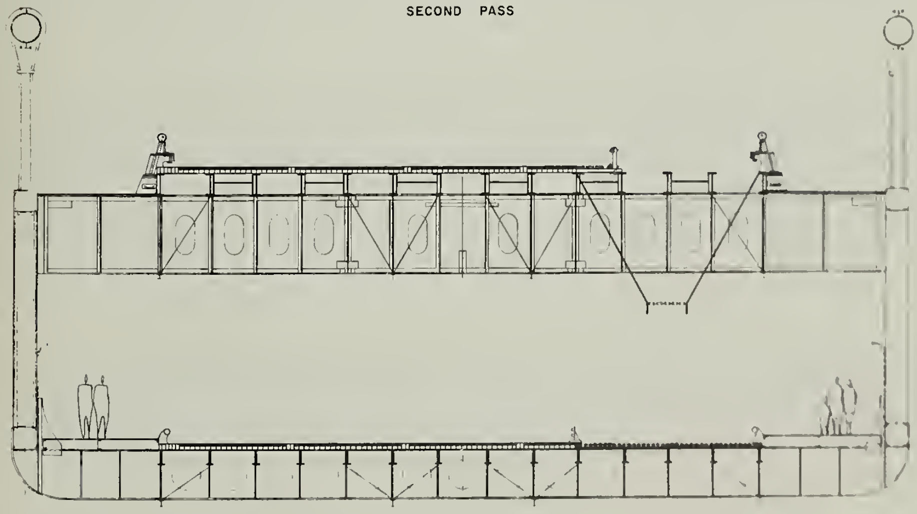
As this work is in progress, sheet metal strips will be threaded between the transverse beams of the grid to retain the



FIRST PASS



SECOND PASS



THIRD PASS

FLOOR SYSTEM - UPPER DECK
THREE PASS CONSTRUCTION

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 15

3-1/4 inches of lightweight concrete fill. A sheet metal dam will be required to block off the concrete to provide the nine inch open lane marker.

1016 - Paving - Upper and Lower Decks

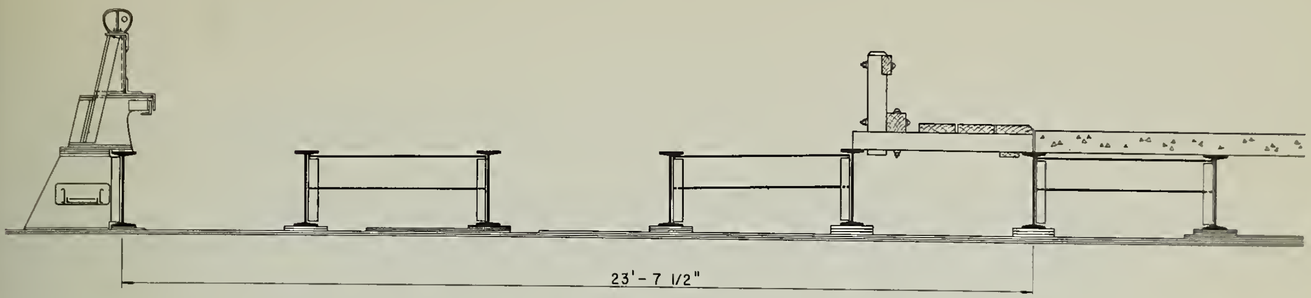
The three different work procedures of removing the present upper roadway slab, the placing of the grid flooring and the paving of the two roadways should be performed by the same contractor. The three operations could be performed in a short working space of about four panels.

During this work the five lanes of one-way traffic will be diverted into four on reaching the working area. The length of deck required for this work, including the diversion of traffic from five to four lanes and the curing of the concrete pavement, would be about 500 feet.

To maintain four full width lanes through the working area, short timber barricades will be moved forward on the stringers as the concrete is removed and then set on the grid as it is placed over the open area. These barriers would also rest on the concrete paving which follows and for the lane shifting (Figure 16).

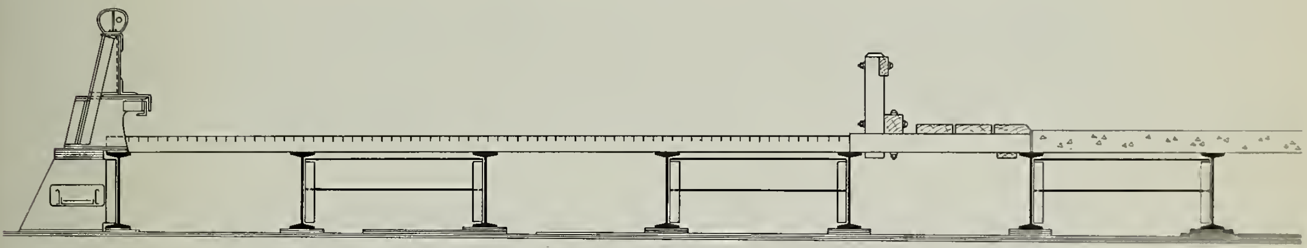
Quick-setting cement will be used in the lightweight concrete pavement. As this concrete has no structural value and is used only to fill the open grid floor, there is little need of protecting it from traffic after it has set. The concrete can cure in the barricaded lane shifting area.

A short work day, from 9 a.m. to 4 p.m., would be required of the Contractor during these three operations providing four full lanes during peak traffic periods.



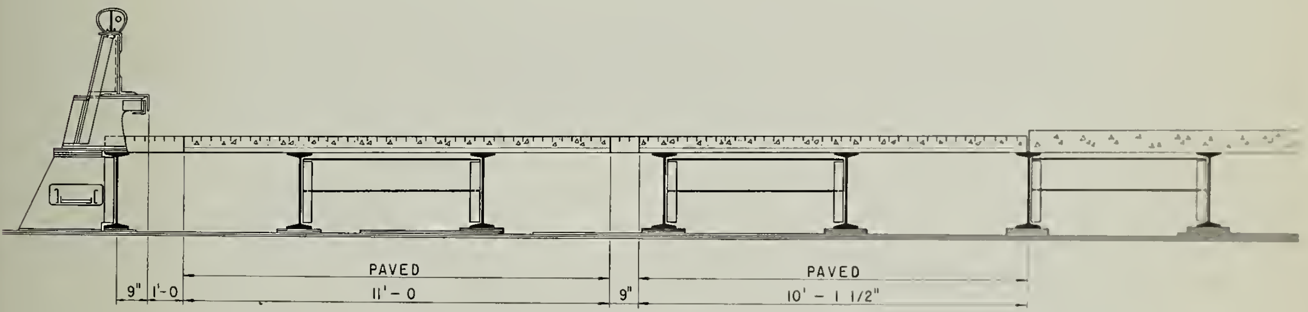
FIRST PASS

FIRST STEP: SLAB REMOVAL



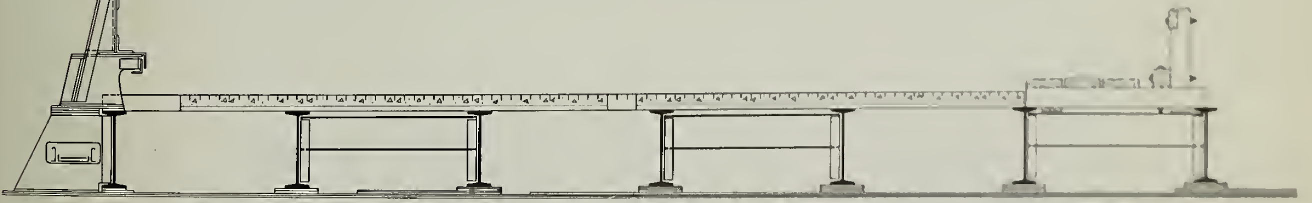
FIRST PASS

SECOND STEP: GRID PLACEMENT



FIRST PASS

THIRD STEP: LANE PAVING



SECOND PASS

FIRST STEP: SAME PROCEDURE AS FIRST PASS

UPPER DECK
SLAB REPLACEMENT

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 16

1017 - Miscellaneous Work

During the course of completion of any large reconstruction project having many contracts of various types of work and employing many different materials, there are items that appear during the construction which require maintenance.

These consist of small repairs to the existing construction, replacement of parts and generally betterments requested by the management. Work of this nature can be let under a contract near the completion of the project.

Also included are many utility relocations, particularly electric power lines along the route of the new construction. Changes are generally made by the companies and charged to the project, unless the agreements are otherwise worded.

There would be a few street and ramp changes and the clearing of several temporary buildings on Federal property, which work could be included in this contract.

1018 - Landscaping

After all improvements pertaining to the project have been completed, a contract is generally awarded for the planting of the bare areas along the rights-of-ways that are in view of the bridge patrons. Along with the planting, there is generally installed an automatic sprinkler system to help maintain the planted areas.

The aesthetics derived from this improvement apply not only to the planting, but to the elimination of sign boards within a reasonable distance from the roadway. A highway landscape architect is ordinarily retained to select the type and size of plants needed for particular areas and to supervise the work.

Besides the beauty that may be derived from the landscaping it can also add to the safety of driving by deadening vehicular noises, eliminating headlight glare and lessening distracting influences.

CHAPTER IV

TYPES OF BRIDGE DECKING

The various component parts or members of the Golden Gate Bridge were proportioned for a calculated dead load and an assumed live load, the latter being distributed and proportioned to produce maximum stresses in the members.

In the redesign of the main and side spans of the suspension bridge to accommodate a lower 60 foot roadway, it has been assumed in this planning that the present dead load of 22,900 pounds per foot of bridge should not be exceeded if a reasonable margin of safety is to remain for any emergencies that could arise during the life of the structure. This is particularly desirable due to the age of the bridge and the exposure it has to the elements (13).

It is essential that any new decking incorporated in the bridge be as light as possible and that any replacement of the upper deck take full advantage of weight-saving possibilities.

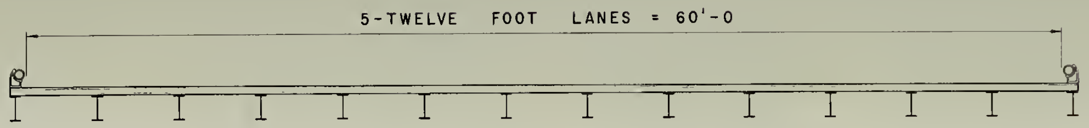
A study was made of several different types of vehicular decking commonly used today that could be made a composite part of the bridge floor system. The following types were reviewed (Figure 17):

1. Six inch reinforced concrete slab weighing 75 pounds per square foot.

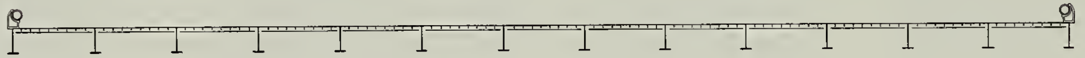
2. Six inch lightweight concrete slab weighing 55 pounds per square foot.

3. Orthotropic design with a 5/8 inch steel deck plate weighing 54 pounds per square foot.

4. Five inch open steel grid decking weighing 20 pounds per square foot. (Type A).



SIX INCH STANDARD OR LIGHTWEIGHT CONCRETE SLAB
FIVE INCH OPEN STEEL GRID



5/8 INCH ORTHOTROPIC STEEL DECK

TYPE	UPPER DECK-Lbs./Ft.			LOWER DECK-Lbs./Ft.			BRIDGE	%
ROADWAY PAVEMENT	SLAB	STRINGER	TOTAL	SLAB	STRINGER	TOTAL	TOTAL	
6" STANDARD CONC. SLAB 150#/□³	4660	1030	5690	4660	630	5290	10980	266
6" LIGHTWEIGHT CONC. SLAB 110#/□³	3420	1030	4450	3400	630	4030	8480	206
5/8" ORTHOTROPIC PLATE	3375	1030	4405	3965	000	3965	8370	203
5" GRID TYPE D	2880	1030	3910	2880	630	3510	7420	180
5" GRID TYPE B	2310	1030	3340	2310	630	2940	6280	153
5" GRID TYPE A	1230	1030	2260	1230	630	1860	4120	100

STUDY

UPPER AND LOWER DECK FLOOR SYSTEMS

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 17

5. Five inch steel grid with various concrete filled lane widths (Type B and D).

It was found that the five inch open steel grid flooring, Type A, was the only decking that could be placed during the period of reconstruction without increasing the dead load of the bridge or overstressing any of the members. The grid on the lower deck would remain open until the new flooring could be installed on the upper deck at which time the grid in both roadways would be filled with concrete.

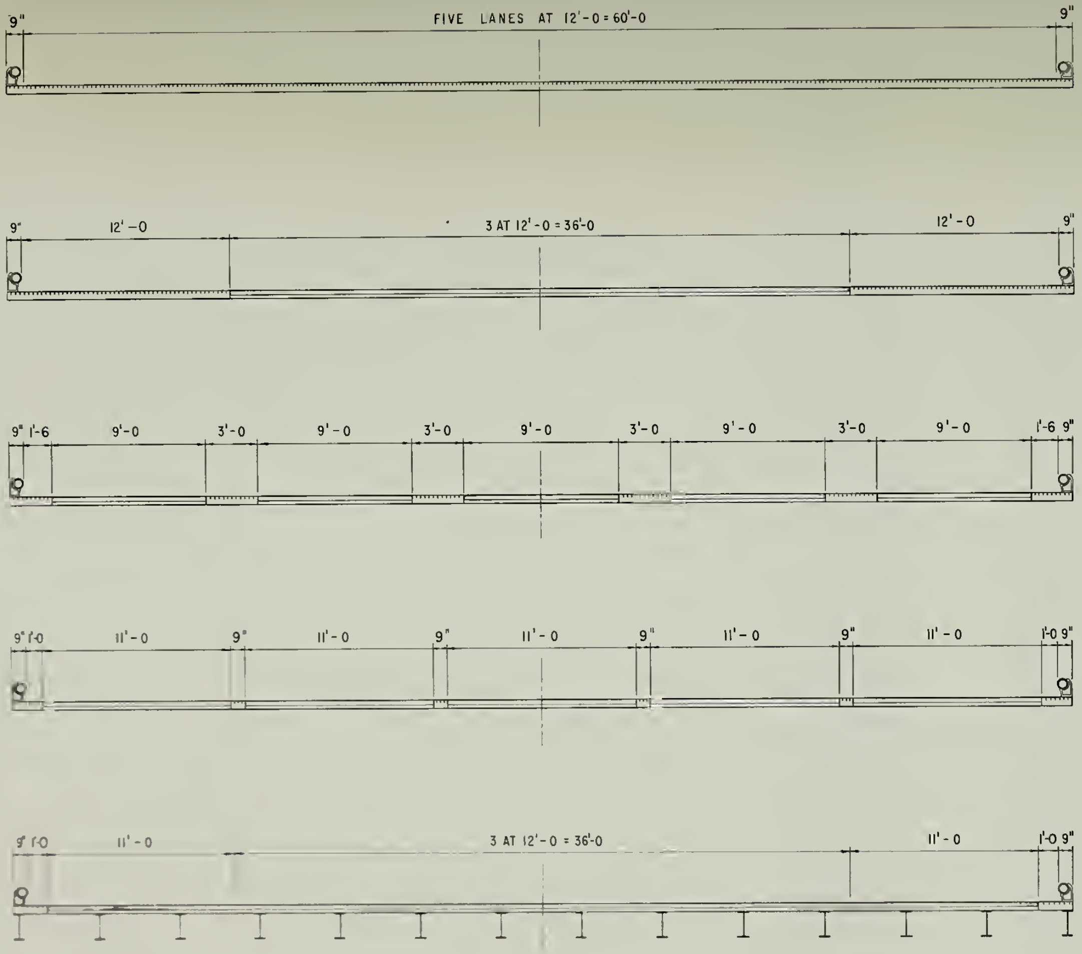
The decking study disclosed that a saving in weight could be obtained by the removal of the upper deck stringers and replacement with lighter weight steel sections. The cost of removal and replacement together with the possible traffic interruption could not be justified; besides, the additional weight saving is not needed in the proposed plan.

The orthotropic type of bridge floor system was not adaptable on the upper deck due to the present arrangement of the floor beams and stringers. The new lower deck floor system was investigated with the steel deck plate participating in taking part of the stringer and floor beam stresses. Most of the weight saving advantage is lost in this type of construction, since a two-inch thickness of asphalt paving, weighing 25 pounds per square foot, is required for a wearing surface in addition to the weight of the steel floor material.

The installation of an open steel grid deck offers possibilities of sizeable savings in weight. The open grid, due to its physical effects upon the driver, does not meet with general public approval. A study was made as to the area of grating which could be filled with concrete without exceeding the allowable dead loads. The weights of the decking with the different areas of lightweight concrete fill are shown on Figure 18.

The Type D flooring, for both the upper and lower decks, appears to be the most suitable for the proposed plan of placing

TYPE	FILL%
A	00
B	59
C	73
D	89
E	94



UPPER AND LOWER DECKS ROADWAY PAVEMENTS

ONE DECK

TYPE	STEEL OPEN GRID	UNIT WT. Lbs.	LIGHT WT. CONCRETE	UNIT WT. Lbs.	TOTAL WT. Lbs.	TOTAL WT. %
A	1 at 61'-6	20	0 at 61'-6	50	1230 000 1230	100
B	2 at 12'-9	20	3 at 12'-0	50	510 1800 2310	188
C	2 at 2'-3 4 at 3'-0	20 20	5 at 9'-0	50	90 240 2250 2580	210
D	2 at 1'-9 4 at 0'-9	20 20	5 at 11'-0	50	70 60 2750 2880	235
E	2 at 1'-9	20	2 at 11'-0 3 at 12'-0	50 50	70 1100 1800 2970	242

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 18

an additional roadway on this crossing. The weight of this deck, when combined with the other material required in the reconstruction, results in a dead load of less intensity than the present. It also provides a suitable, safe pavement with excellent riding characteristics since the transverse slab expansion joints would be eliminated.

The nine inch open strip will provide a physical warning that the driver will see, hear and feel when contacted by the vehicle tires. At night the lower roadway's illumination will filter through the strip in the upper roadway resulting in a light line separating the traffic lanes the full length of the bridge.

A similar effect would be experienced on the lower roadway. The overhead lighting would reflect off the concrete paving and be absorbed in the nine inch open grid strip. This would produce a dark line of demarcation between the lanes.

CHAPTER V

BRIDGE DEAD LOADING

It has been stated in the "Project Description," Chapter II of this report, that a second deck can be added to the Golden Gate Bridge without increasing the present weight of the structure.

Reports have been submitted to the District for the reconstruction of the bridge for use by lightweight rapid transit trains (12) also, for a second deck to accommodate vehicular traffic (18).

The Bridge Board authorized a review of the San Francisco Bay Area Rapid Transit District's report of March, 1961 (12) The findings of the review indicated that the operation of rapid transit trains over the bridge would not be recommended (13), and the reasons for this were supplemented in the report of April, 1962 by a Board of Consultants (14).

Taking into consideration the effects of overloads on all individual units and members of the bridge, it is believed advisable that the present loadings with resultant stresses in the various members should not be exceeded in any reconstruction plan.

As originally built the suspension spans were designed for an assumed uniform dead load of structure suspended from the towers of 21,000 pounds per linear foot of bridge (4). As actually completed in 1937 the dead load was estimated to be 21,300 pounds in the center span (Figure 19), or 10,650 pounds per foot of cable.

In subsequent years there were added a second or bottom lateral system weighing 1,400 pounds per foot of bridge and

supports for maintenance platforms weighing 200 pounds per foot (13). These additions increased the dead load of the center span to its present value of 11,450 pounds per foot of cable.

It appears inconsistent to state that the weight of a second deck can be added to the present structure and not increase its dead load. This could not be accomplished unless certain parts or portions of the structure are removed and replaced with modern materials of greater strength and less weight, and by the use of lighter roadway decks, thus reducing dead loads with resulting lower stresses.

The plan of accomplishing this new construction is presented in the following table (Figure 19). It considers the removal of all surplus dead loads and the concurrent placing of the new material for the new lower roadway. It should be noted that the new loading during the construction, Item V, at no time exceeds the load of 11,450 pounds per foot of cable that now exists. The end result will be accomplished through a careful but practical scheduling of the work to be performed.

It is assumed that all wind bracing steel will be progressively removed panel by panel, starting at the south end of the bridge.

The quantities of materials in Item IV which will be removed with the lower level wind bracing consist of the following:

1. Concrete sidewalk slabs.
2. Handrailing and electroliers.
3. Steel sidewalk beams and bracing.
4. Ladders and platforms.
5. Lower chord knee bracing.
6. Web openings - upper deck floorbeams.

RECONSTRUCTION - GOLDEN GATE BRIDGE
COMPARISON OF LOADINGS - ONE CABLE

(For Weight Per Foot of Bridge Double the Values in the Table)

		EXISTING			PROPOSED					
		SIX 10-FOOT LANES			TEN 12-FOOT LANES					
		Concrete Slab			Open Grid - Type A			Filled Grid - Type D		
Item	Description	Year	Weight	Lbs. /Ft.	Year	Weight	Lbs. /Ft.	Year	Weight	Lbs. /Ft.
I	Assumed D. L.	1935		10, 500						
II	Actual D. L.	1937	+ 150	10, 650						
III	Steel Alterations	1954	+ 800	11, 450	1967	- 800	10, 650			
IV	Steel Alterations				1967	- 930	9, 720			
V	Lower Deck Grid				1968	+1610	11, 330			
VI	Slab Removal				1969	-2800	8, 530	1969	-2800	8, 530
VII	Upper Deck - Grid				1969	+ 590	9, 120	1969	+ 590	9, 120
VIII	U & L Decks - Paved							1970	+1650	10, 770
IX	Utilities				1970	+ 70	9, 190	1970	+ 70	10, 840
X	Highway L. L.	1935		1, 500	1969	+ 600	2, 100	1969	+ 600	2, 100
XI	Sidewalk L. L.	1935		500	1969	- 210	290	1969	- 210	290
	Total DL + LL + SW LL			13, 450			11, 580			13, 230
	DL + LL			12, 950			11, 290			12, 940

FIGURE 19

The removal will reduce the existing 11, 450 pounds per foot of cable to 9, 720 pounds.

The new floorbeam will be raised into position and bolted to the outer gusset plate of the lower chord and to the vertical members of the stiffening truss. The remainder of the floor steel will follow, consisting of the roadway and sidewalk stringers with wind bracing and the steel grid flooring. The new floor system will raise the dead load from 9, 720 pounds per foot of cable to 11, 330 pounds which is less than the present 11, 450 pounds per foot.

Prior to the start of the removal of the present upper deck concrete slab, one-way traffic will be inaugurated on the bridge and approaches. The progressive panel-by-panel removal of the slab, the placing of the open grid steel flooring, and the paving of both the upper and lower decks will be accomplished in three complete and continuous passes across the bridge (Figure 15).

The complete removal of the present upper roadway slab will reduce the bridge dead load to 8, 530 pounds per foot of cable. The placing of the open steel grid will raise the dead load to 9, 120 pounds per foot (Figure 19).

Immediately following the above two operations, the upper 3-1/4 inches of the five inch grid will be filled with lightweight concrete on both the upper and lower decks. This will raise the dead load to 10, 770 pounds per foot of cable.

The three operations with the placing and moving of the temporary barriers are shown in Figure 16.

An estimated dead load of 200 pounds per cable for conduits and miscellaneous items was allowed in the original planning for the bridge. An additional 70 pounds per foot of cable

was added in this plan for possible future utilities which increases the total dead load to 10,840 pounds per foot of cable compared to the 11,450 pounds that now exist.

If the ten lanes were not paved and the grid flooring remained open, the dead load per foot of cable would be 9,190 pounds compared to the 10,500 pounds which was the assumed dead load at the time of the original planning for the main crossing.

With the addition of the live load, which is explained in Chapter VI, the total load per foot of cable of 13,230 pounds will be less than the original assumed dead and live load, including subsequent improvements of , of 13,450 pounds.

CHAPTER VI

DESIGN CONSIDERATIONS

The American Association of State Highway Officials (AASHO) "Standard Specifications for Highway Bridges" is used as a control in the design of vehicular structures, particularly when Federal Highway Funds are appropriated to assist in the construction (11). These specifications apply in general to all highway bridges, but do not contain the special provisions necessary for the type of bridge that is being considered. The Introduction to the Specification states the following:

> "Primarily, the specifications set forth minimum requirements which are consistent with current practice, and it is expected that certain modifications will be necessary to suit local conditions. They apply to ordinary highway bridges, and supplemental specifications may be required for unusual types and for bridges with spans longer than 300 or 400 feet."

It has been the practice in the design of long span bridges to use all parts of these specifications where applicable, and to follow common practice where deviations are essential for the proper proportioning of the structure for safety and economy. One of the variances from these specifications has been the intensity of the live loading that should be applied to long spans.

Live Load

The assumed live loading used during the planning for the Golden Gate Bridge was:

Loading	Live Loading per ft. of bridge
Vehicular - Six lanes @ 500 lbs. per lane =	3,000 lbs.
Sidewalk - Two 10-foot walks @ 50 lbs. per sq. ft. =	1,000 lbs.
Total	4,000 lbs.

This loading was used in the original design in the proportioning of all bridge members except for the modifications indicated in the final report of the Chief Engineer (4). The floor system was designed for a 24-ton truck in each lane with an impact factor of 25 percent and a reduction factor of 75 percent for a large number of lanes loaded.

Types of vehicles comprising the traffic on the various highways throughout the nation are quite varied, principally due to the non-uniformity of restrictions placed by the indivudal states on the size and weight of the commercial carriers. The pattern of traffic including both automobiles and all the various types of trucks further complicates the problem of standardizing a live loading for long span bridges.

It has been acknowledged by those involved in any structural study of this bridge that the live loadings used in the original design are severe and would probably never occur during the life of the structure. Those who have reported on the ability of the structure to carry additional dead loads have applied a lighter live load of the same or similar intensity to that used in this report.

Probably the only loading investigation of the commercial type of vehicle for long span bridges was made on the lower deck of the San Francisco-Oakland Bay Bridge in 1953. The three-lane roadway with two directional traffic, assigned exclusively for commercial vehicles, was ideal for that study. The

results of the study were published in the 1954 Transactions of the American Society of Civil Engineers (9) and the loading recommended in the study has been used in the design and reconstruction of some of the larger bridges now in existence.

This vehicular loading in conjunction with the sidewalk loading of the AASHO Specification (11) when applied to the suspended structure of this bridge results in the following:

Loading	Live Loading per ft. of bridge
Vehicular - Ten lanes @ 0.75 x 560 lbs. per lane	4,200 lbs.
Sidewalk - Two 10.5-foot walks @ 28 lbs. per sq. ft.	590 lbs.
Total	4,790 lbs.

In the design of any span of relatively short length, whether it be the roadway slab, girders or trusses, there would be a few occasions in the life of the structure when a number of the heaviest highway vehicles could occupy certain floor areas to produce maximum stresses in bridge members. For longer spans and wider roadways, this condition would occur less often and for a span length of the magnitude of this crossing, the possibility of the entire bridge being loaded with trucks is remote, particularly when more than 90 percent of the vehicles in use are automobiles.

This latter loading (9) would be used in proportioning new bridge members and checking all stresses in existing portions. The floor system would be designed for the AASHO H-20-S16 truck loading with a reduction factor of 0.75 when more than three lanes are occupied.

Impact is provided for by adding a varying percentage to

the weight of vehicles in accordance with the length loaded. The impact effects resulting from the live loading on the suspended spans of this crossing, due to their great lengths, are small and need not be considered. The impact factor and other loading conditions where applicable would conform to the AASHO Standards (11).

Wind

The effect of wind upon the Golden Gate Bridge is quite difficult to analyze due to the great length of the bridge and the vulnerability of the site to the actions of the elements. Wind can strike the structure from almost any angle and gusts can hit all or any portion of the spans.

The actual effect of external forces acting upon the proposed reconstructed bridge can only be obtained by wind tunnel tests on a scale model of the bridge. Until a thorough investigation of this type has been made, the effects of structural changes on the aerodynamic stability of the bridge can only be assumed from the results of previous studies on individual elements similar to the proposed system.

Wind tunnel experiments on various types of flooring have indicated that partially filled grid floors with openings between the lanes as proposed in this plan improve the stability of the bridge under wind loads.

The openings in the upper and lower deck floor beams will reduce the longitudinal effects of a quartering wind and thereby contribute to the stability of the structure.

The removal of sidewalks, railing and light standards from the upper deck will partially compensate for the slight increase in area exposed to wind caused by the addition of the proposed lower deck. It is believed that the total effect of the structural changes in the proposed plan will be to improve the

stability of the bridge under wind loads.

Earthquake

The occurrence of several earthquakes during the life of the bridge has confirmed the findings of the designers that earthquake is not a major force in the design of the bridge. Since no additional mass has been added and since the basic dynamic system remains unchanged, it can be reasonably assumed that the structure would be no more vulnerable to shock due to reconstruction.

Deflections

The dead load under the proposed reconstruction plan is less than the dead load which presently exists on the bridge and the proposed live loading is little more than the live loading assumed in the original design. The total dead and live load deflection for the proposed construction will probably be approximately the same as now exists. Accordingly, the present navigation clearance will be decreased by approximately the amount which the proposed lower deck floorbeams project below the lower chords of the stiffening trusses. This dimension, as presently proposed, is six feet.

Any reconstruction of the bridge over the navigation channel would require a permit from the Corps of Engineers. In view of the benefits to be obtained from the proposed reconstruction plan, any such small decrease in vertical clearance would probably be acceptable.

CHAPTER VII

BRIDGE TRAFFIC

Vehicular traffic on the Golden Gate Bridge has been a subject of intensive study from the standpoints of future projections, maximum capacity, and suitable means of increasing the capacity.

The vehicular capacity of a crossing cannot be measured with certainty. The maximum capacity of a vehicular structure can only be obtained when its lanes have reached their practical capacities, in each direction of travel, over a period of 24 hours. This would never happen since new facilities would be demanded by the traveling public long before anything approaching this maximum could be reached.

There are, however, methods of rating the capacities of roads and bridges which are accepted by state and federal agencies. Standards for the rating of these facilities in terms of their traffic carrying abilities have been published in the Highway Capacity Manual (7). These standards have been used in computing the capacities shown in this report.

The definition of capacity as defined in the Manual is the maximum number of vehicles that can pass a given point on a lane or roadway during one hour under the prevailing road and traffic conditions. This definition has been separated into two capacities: "possible" and "practical."

The possible capacity of a lane or roadway is defined as the volume of traffic that cannot be exceeded in actuality without changing one or more of the conditions that prevail.

The practical capacity is defined as the maximum number of cars that can pass a given point on a roadway or in a

designated lane during one hour without the traffic density being so great as to cause unreasonable delays, hazards or restrictions to the drivers' freedom to maneuver under the prevailing roadway and traffic conditions.

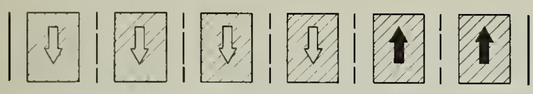
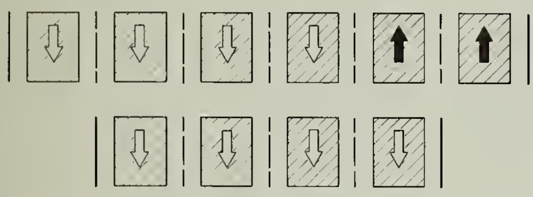
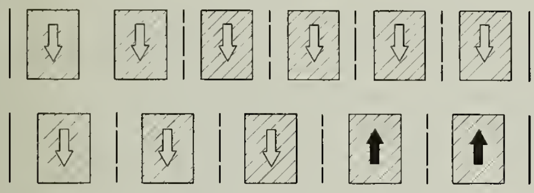
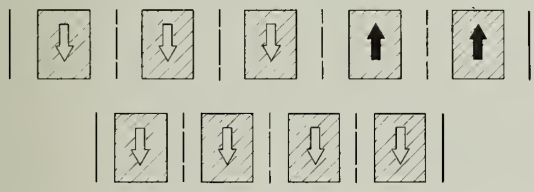
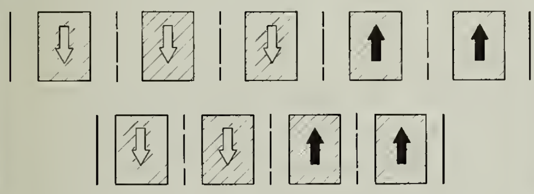
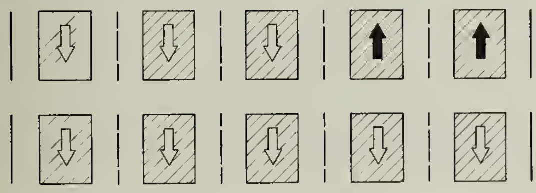
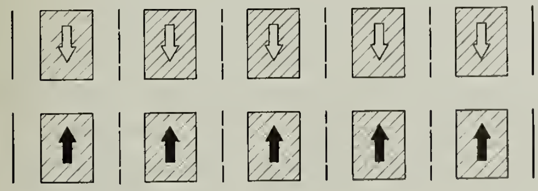
In determining these capacities various existing physical conditions are taken into consideration in arriving at the number of vehicles a certain lane will accommodate; such as the type of vehicle, autos alone or mixed; lane width, shoulder width, opposing or separated lanes, rolling or level terrain, or other peculiar conditions.

Various traffic handling plans for the existing bridge and for alternative double deck were studied which considered the number and width of lanes that could be incorporated in the structure, direction of flow and the types of vehicles using the roadways, the purpose being to determine which arrangement would provide the greatest capacity, safety, comfort and also prolong the life of the structure as a principal traffic artery.

The combinations of lane arrangements that were studied are shown in Figure 20 with their practical and possible bridge capacities as computed by the Highway Capacity Manual (7).

The present single deck operation with four lanes in one direction during peak traffic flow gives a possible capacity of 5,840 vehicles per hour as computed by the Manual. A traffic survey made in 1965 indicated a count of 5,895.

The arrangements giving the maximum possible capacities for the present single deck, for two decks with the lower roadway for automobiles only and for two decks with mixed traffic on each level, are as follows:

PLAN		TYPE	FLOW	VEHICULAR CAPACITY			
				PRACTICAL		POSSIBLE	
1		MIXED	4 S 2 N	4300 1950	6250	5840 2710	8550
2		MIXED	2 N 4 S	1950 4300		2 710 5840	
		AUTOS	4 S	5350	11600	7 140	15690
3		MIXED	6 S	6880		9170	
		MIXED	2 N 3 S	2420 3730	13030	3285 5030	17485
4		MIXED	3 S 2 N	3730 2420		5030 3285	
		AUTOS	4 S	5350	11500	7140	15455
5		MIXED	3 S 2 N	3730 2420		5030 3285	
		AUTOS	2 N 2 S	2375 2375	10900	3270 3270	14855
6		MIXED	3 S 2 N	3730 2420		5030 3285	
		MIXED	5 S	6410	12560	8545	16860
7		MIXED	5 S	6410		8545	
		MIXED	5 N	6410	12820	8545	17090

THEORETICAL BRIDGE CAPACITY

HIGHWAY CAPACITY MANUAL

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 20

Possible Capacity

Plan	One Direction	%	Two Directions	%
1	5,840	100	8,550	100
4	12,170	208	15,455	181
6	13,575	236	16,860	197
7	8,545	146	17,090	200

With five 12 foot lanes on each deck, and with the lower deck and one lane of the upper deck reversible, Plan 6 gives the maximum of 13,575 vehicles in one direction. This plan has the five 12 foot lanes for mixed traffic on each deck. Plan 7 gives the maximum for two-directional traffic which, as indicated, is double that of Plan 1. This plan has five 12-foot lanes on each deck for mixed traffic. Reversing the lanes for the Plan 6 operation cannot be satisfactorily accomplished due to the limited space on each end of the bridge. However, it is a simpler solution to obtain the maximum unidirection traffic flow than Plan 4, as the automobiles would not have to be separated from the trucks. Plans 1, 4 and 6 would not conform to freeway standards.

The planning for a roadway to provide for one type of traffic such as automobiles, or for the changing of the direction of flow in traffic lanes during the morning and evening peaks would require long approaches on each end of the bridge for the required traffic interchange. This length is needed for the weaving distances required for the separating of vehicles for a particular deck, acceleration and deceleration lanes for ramps, the standard distances between the roadway sign and the area required for lane separations, lighting standards and barriers.

It does not appear feasible to provide the land areas needed to accommodate the aforementioned facilities for any of the lane arrangements of Plans 2 to 6 due to the present site conditions. Both ends of the bridge are located on high rise promontories, which with the present location of bridge improvements, such as the toll plaza, administration building,

parking areas, streets and roads, would not be adaptable to any suitable roadway connections.

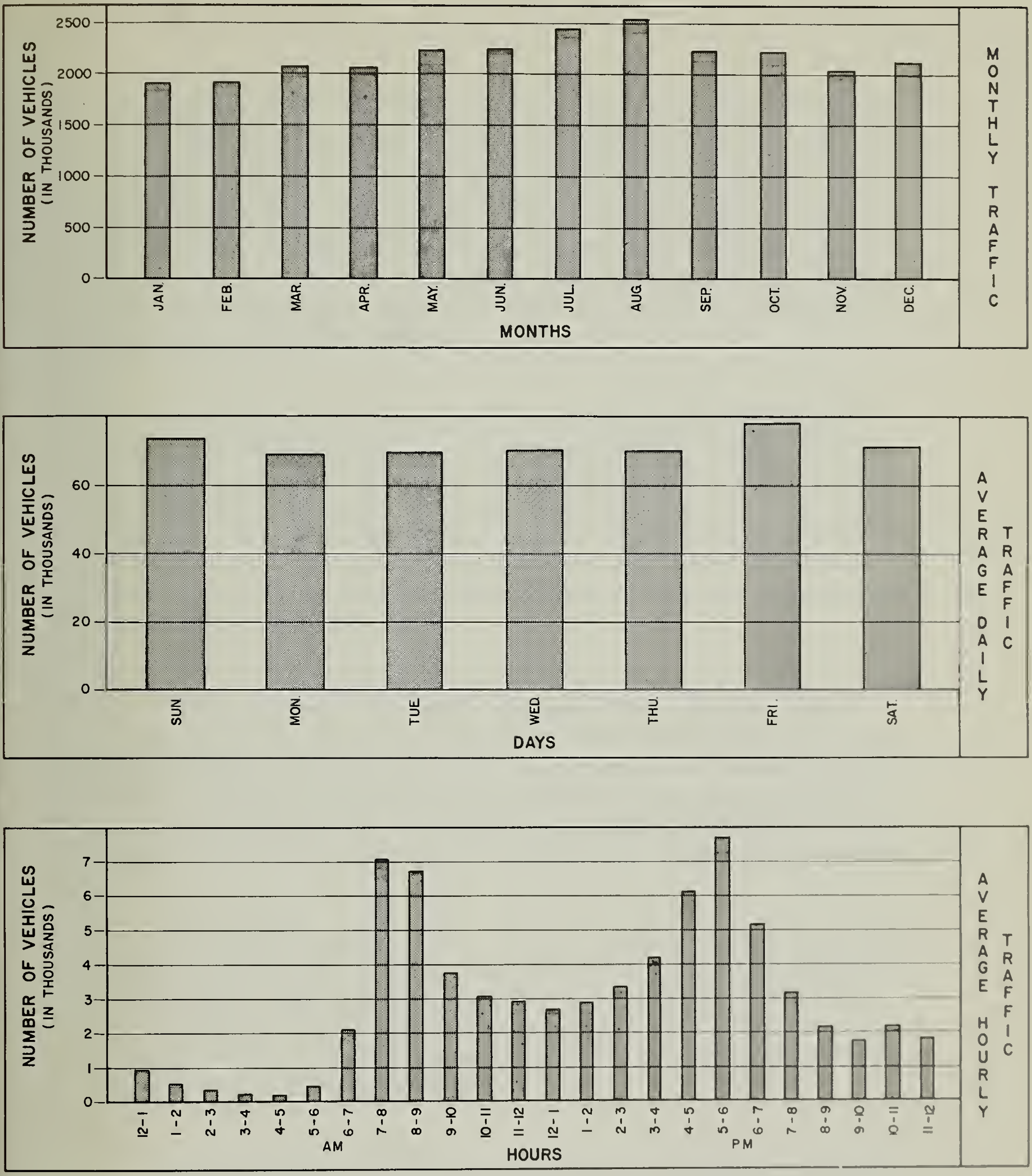
The one-way roadways of Plan 7, requiring no space for traffic weaving and with a minimum of connecting ramps would be the only plan that would meet freeway standards. It would require less right-of-way and would be the least disturbing to existing facilities. The roadway connections at the ends of the project would fit into any future freeways and become a part of the same.

Lane arrangements for long span crossings generally provide for the peak flows although the location of the bridge can and does have some effect upon the hours and the day of the week that these occur. If the bridge connects two municipalities the heaviest traffic can be expected on weekdays and the lesser volumes on weekends and holidays.

The Golden Gate Bridge has its maximum flow during the week on Friday due to the exodus of people wishing to spend their weekend in the country; however, their return on Sunday, the next highest day, is generally met by those in the opposite direction who have been attending public attractions in San Francisco (Figure 21). These incidents cause a double peak and can only be satisfied with an equal number of lanes in each direction. These double peaks are common occurrences on bridges with a somewhat balanced traffic flow in each direction during the peak periods.

The average hourly count for traffic in two directions on the Golden Gate Bridge is shown in Figure 21 and is typical of crossings carrying largely commuter traffic having peak flows from 7 a.m. to 9 a.m. and from 4 p.m. to 7 p.m.

The capacity of a crossing can be materially increased by voluntary changes in the traveling habits of the patrons in avoiding peak traffic flows as well as the rescheduling of the runs of



MONTHLY, DAILY & HOURLY TRAFFIC COUNTS
OCTOBER 1965

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 21

the commercial carriers to avoid delays in travel. The gradual change that is taking place in the peak periods of transit is shown in Figure 22 which indicates that more people are leaving later in the morning for their places of business and arriving home later in the evening. These timing changes cause the peak periods to extend over a longer interval of time, resulting in a greater bridge capacity. This extension does not lend to the convenience of travel nor does it benefit the economy of routine commercial traffic.

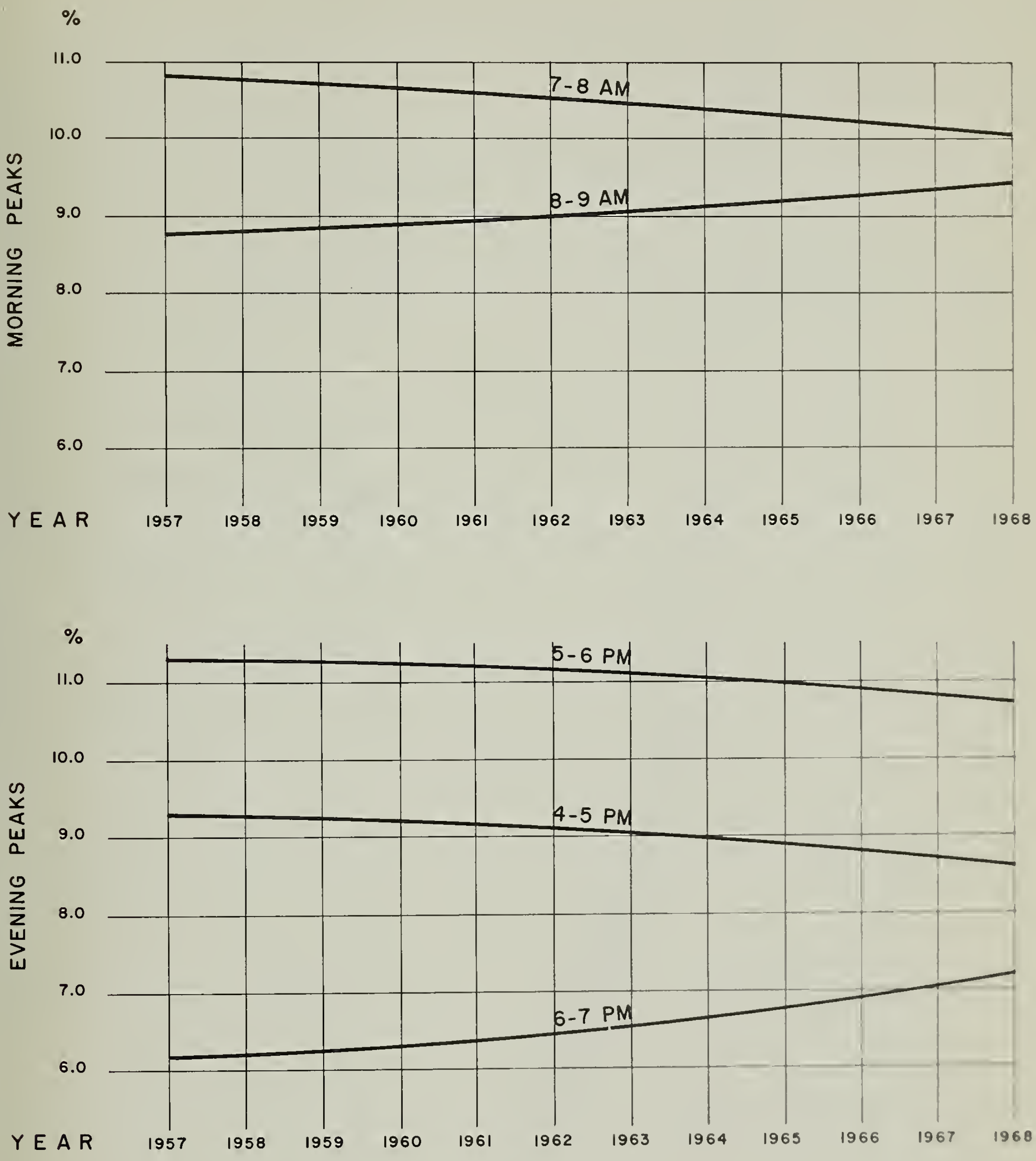
These traffic changes on the Golden Gate Bridge have been occurring for some years in the past. The number of vehicles crossing the structure will gradually increase over the estimated 25,000,000 vehicular capacity; however, at a declining rate. The average annual rate of traffic growth is shown in Figure 23. The data represented on this chart was taken from "The Traffic Report, Golden Gate Bridge and Approaches," dated July, 1965 (20).

The question as to when any new double decking plan would reach its capacity in the future and when plans for a new crossing to serve the North Bay area should be started is difficult to estimate due to the many changes that could take place prior to, during or after any reconstruction plan for the bridge is undertaken. It would depend mainly upon population growth.

The most reliable data on which to base any future traffic predictions are the present vehicular counts for the crossing and the data available on population growth of the North Bay communities. The latter can only be used as a guide since it would be difficult to estimate the percentage of this growth that would use the present facility.

It is possible to predict as to what could happen if either of the following takes place:

1. No reconstruction of the bridge to increase its present capacity.



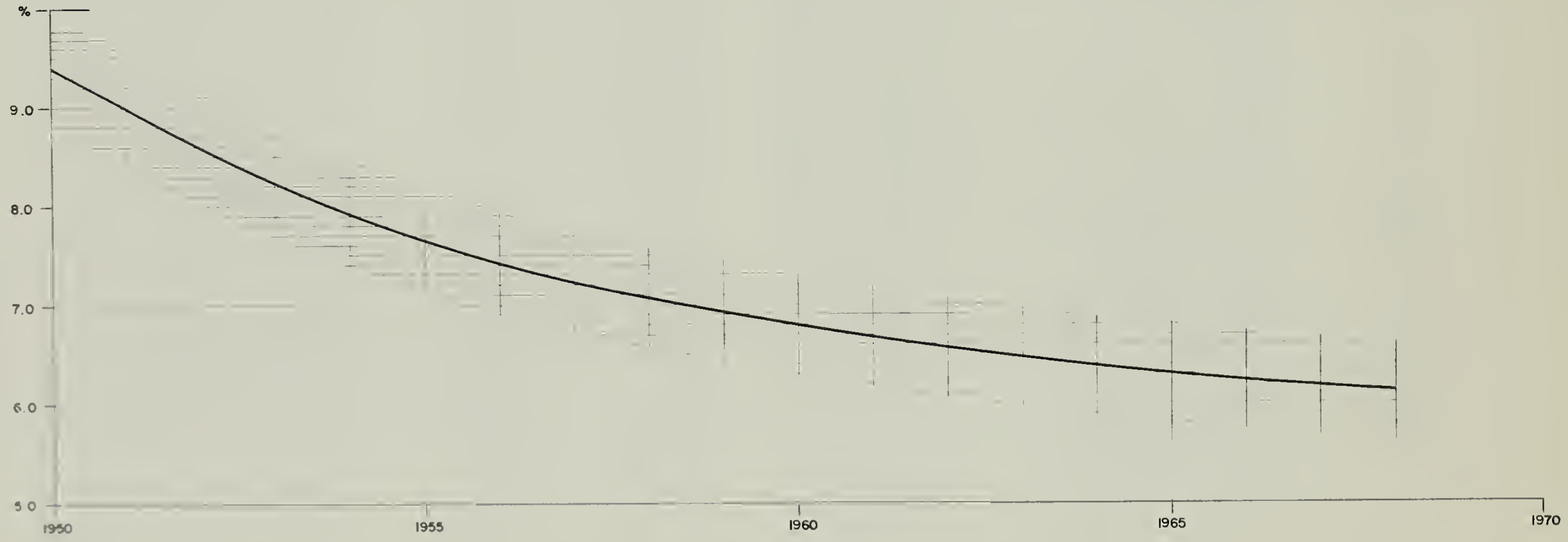
MORNING AND EVENING TRAFFIC PEAKS

PERCENTAGE OF 24 HOUR VEHICULAR FLOW

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY
TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 22

	1950					1955					1960					1965					1970
	9.4	9.4	9.4	9.4	9.4																
		8.5	8.5	8.5	8.5	8.5															
			10.7	10.7	10.7	10.7	10.7														
				4.3	4.3	4.3	4.3	4.3													
					4.6	4.6	4.6	4.6	4.6												
						7.8	7.8	7.8	7.8	7.8											
							11.6	11.6	11.6	11.6	11.6										
								6.3	6.3	6.3	6.3	6.3									
									4.7	4.7	4.7	4.7	4.7								
										7.2	7.2	7.2	7.2	7.2							
											6.9	6.9	6.9	6.9	6.9						
												6.4	6.4	6.4	6.4	6.4					
													6.8	6.8	6.8	6.8	6.8				
														5.3	5.3	5.3	5.3	5.3			
															6.7	6.7	6.7	6.7	6.7		
																5.0	5.0	5.0	5.0	5.0	
RETARDED PERCENTAGE OF ANNUAL INCREASE	9.4	9.0	9.5	8.2	7.5	7.2	7.8	6.9	7.0	7.5	7.3	6.3	6.4	6.5	6.4	6.0	5.8	5.6	5.8	5.0	



AVERAGE ANNUAL RATE OF TRAFFIC GROWTH

(5 YEAR RETARDED AVERAGE)

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO , CALIFORNIA

FIGURE 23

2. Assuming a second deck, Plan 7, Figure 21, were completed and in operation by the end of the year 1966.

Considering the first possibility, that the bridge and approaches remain and function as they are at present, traffic will continue to increase at a declining rate as shown on Figure 23. Peak vehicular flow will gradually spread over a three hour period from 6:30 a.m. to 9:30 a.m., and in the evening from 3:30 p.m. to 7:00 p.m. The midday traffic will also increase.

It has been observed on several of the Bay toll bridges that, after a comfortable capacity has been reached, an additional traffic increase has occurred before delays in crossing became intolerable and other ways and means of reaching their destinations have been sought by patrons.

The fluxtuation in traffic growth of the existing seven toll crossings is shown on Figure 24, "Total Monthly Vehicular Traffic, Bay Area Bridges." (19)

An illustration of what occurs when a crossing reaches its traffic carrying capacity is shown by the graph of the Carquinez Bridge traffic.

Prior to 1950 the growth rate was parallel to other bridges in the area. After about 1952, there was a leveling of traffic indicating the Bridge had become congested. The relation between the traffic volumes in 1950 and subsequent to 1952 indicate that the congested capacity of the Bridge is approximately 40 percent more than the confortable capacity. If this relationship is applied to the Golden Gate Bridge and the comfortable capacity is estimated at 25 million vehicles per year, it is estimated that the congested capacity of 35 million vehicles per year will be reached in about 5 years.

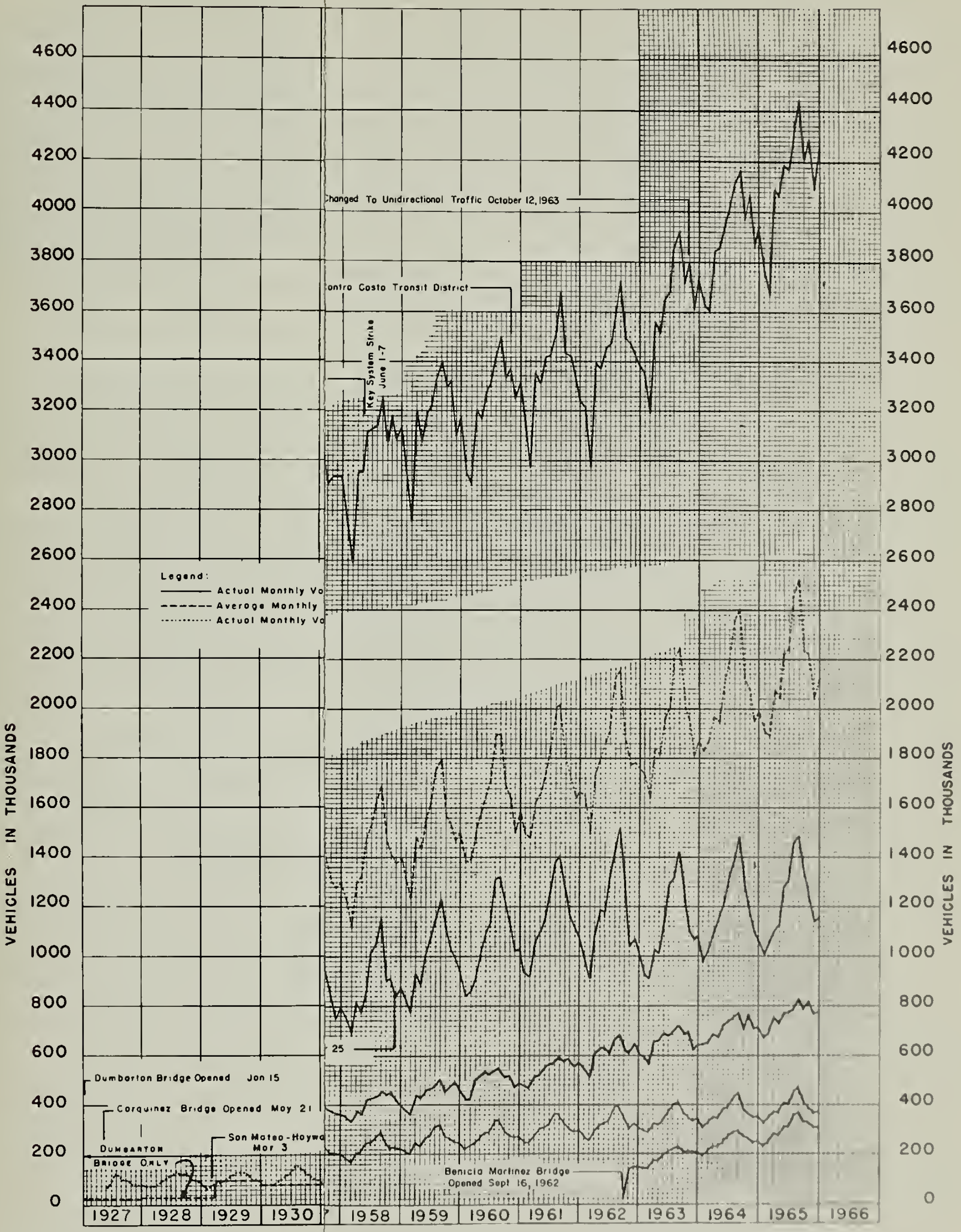
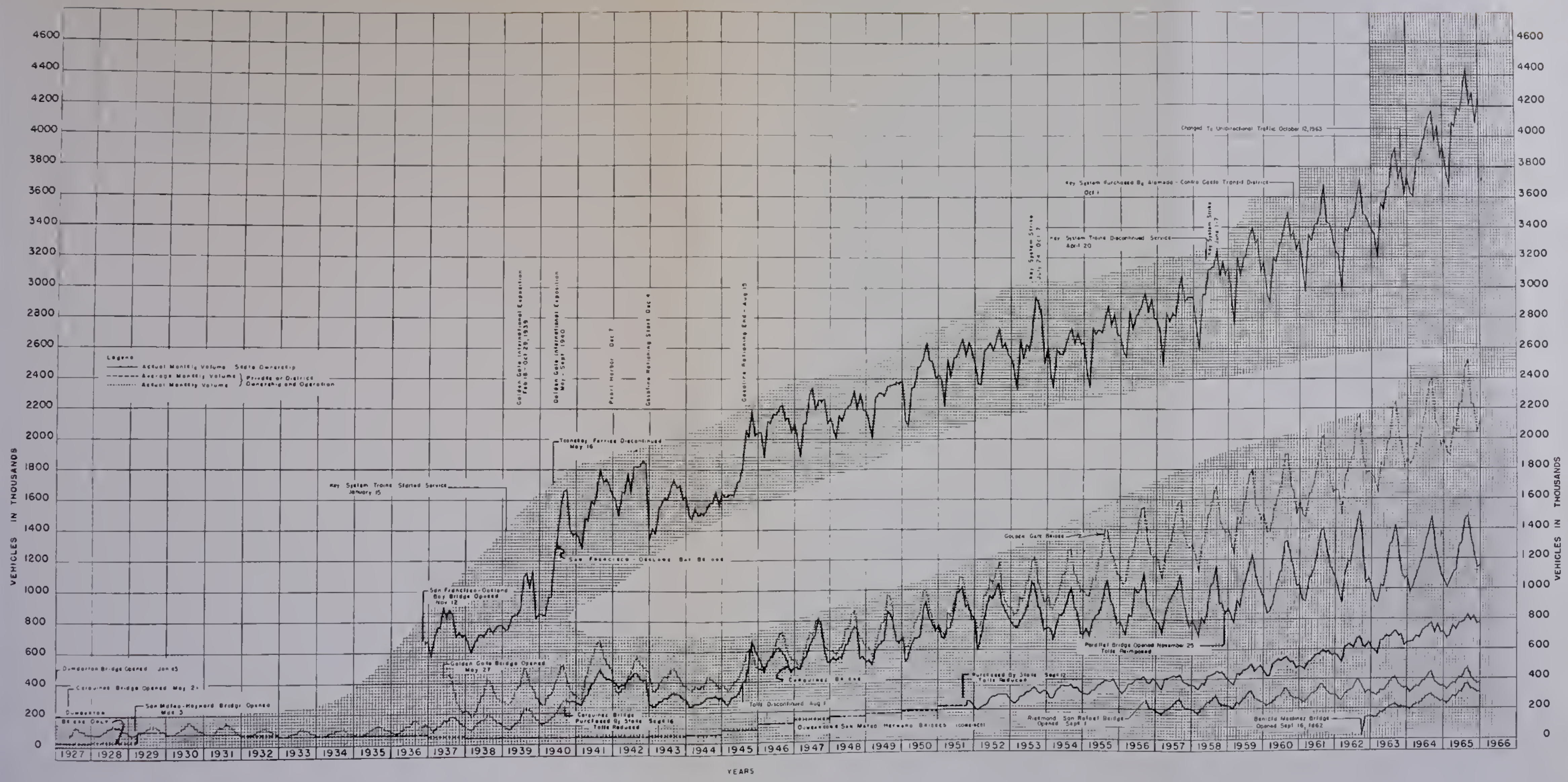

VEHICLES IN THOUSANDS
4600
4400
4200
4000
3800
3600
3400
3200
3000
2800
2600
2400
2200
2000
1800
1600
1400
1200
1000
800
600
400
200
0
hanged To Unidirectional Traffic October 12,1963
ontro Costa Transit District
Key System Strike June 1-7
Legend:
Actual Monthly Vo
Average Monthly
Actual Monthly Vo
25
Dumbarton Bridge Opened Jan 15
Corquinez Bridge Opened May 21
San Mateo-Haywa
Mar 3
DUMBARTON BRIDGE ONLY
Benicia Martinez Bridge Opened Sept 16, 1962
1927
1928
1929
1930
1958
1959
1960
1961
1962
1963
1964
1965
1966

FIGURE 24

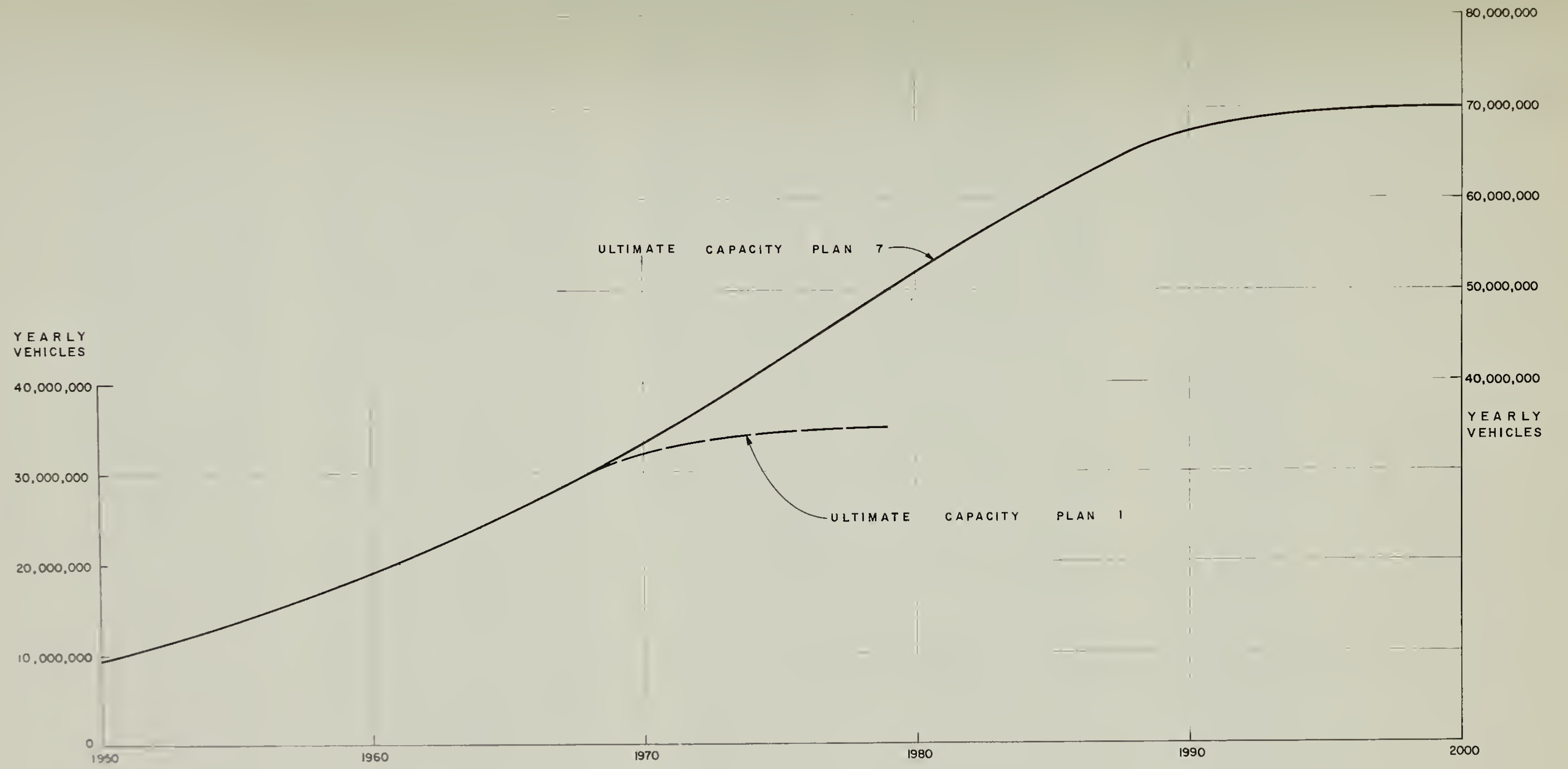


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF BAY TOLL CROSSINGS

TOTAL MONTHLY VEHICULAR TRAFFIC
BAY AREA BRIDGES

FIGURE 24

Considering the second possibility and assuming that a second deck were installed and Traffic Plan 7, Figure 20, were utilized and freeway connections on each end of the bridge were completed as funds were made available, the comfortable capacity of 40 to 50 million vehicles per year would be reached in 10 to 15 years. If this is reasonable to expect, and the ultimate capacity is somewhat higher as indicated in Figure 25, there should be no need for additional vehicular crossing facilities prior to 1985.



PROJECTED YEARLY TRAFFIC

BASED ON

FREEWAY CONNECTIONS TO BRIDGE

GOLDEN GATE BRIDGE
DOUBLE DECKING STUDY

TUDOR ENGINEERING COMPANY
SAN FRANCISCO, CALIFORNIA

FIGURE 25

CHAPTER VIII

SUMMARY

It is of prime importance in any plan of reconstruction that, whatever changes and additions are contemplated, the bridge must be preserved in a first-class condition with a conservative margin of safety to serve highway traffic.

The bridge as reconstructed in conformance with the proposed plan will constitute a traffic facility having a higher degree of safety for the traveling public than now exists. The bridge will have two decks, each with five 12 foot lanes of one-way traffic, the upper deck carrying southbound traffic and the lower deck carrying northbound traffic. The lower deck will have a minimum vertical clearance of 16 feet and horizontal clearances will conform to accepted standards. The lane widths and clearances will conform to freeway standards so that the bridge will fit into the State Highway freeway system. The bridge approaches can be adapted to the two deck plan within the limits of good highway practice for alignment and grades and can be adjusted to fit any freeway plan proposed for the connecting streets and roads.

The proposed plan provides a second deck on the bridge without exceeding the loads and stresses that now exist. This is accomplished by removing some of the dead load elements and replacing them with lighter materials of higher strength. The application of the more realistic live loads used in the more recent designs of long span bridges, together with lighter dead loads, produces total stresses which are no greater than those used in the original design, as modified.

To implement the plan for a second deck, major structural changes will be required in the floor systems, lower lateral bracing system, steel towers, steel arch span, steel approach spans, and concrete pylons. There appears to be no unusual difficulty in accomplishing this work and it can proceed

with little or no interference with traffic. The rearrangement of structural elements of the bridge will in no way jeopardize the safety of the structure.

It is believed that the revised wind bracing system which includes the steel floors on each deck, together with the vertical and horizontal venting, will improve the stability of the bridge under wind loads.

Since the stresses resulting from the new design loads will be no greater than those now existing, there will be no adjusting, reinforcing or replacing of any of the main members of the suspended spans. The vertical deflections of the spans will have approximately the same magnitude as under the present loading.

The relocation of the sidewalks from the upper deck to the lower deck will permit the installation of a suicide barrier which can be built to harmonize with the structural elements without adversely affecting the appearance of the bridge. The presence of sidewalks on the lower deck will be an asset to the maintenance forces.

Computations of traffic capacities by accepted standard methods indicate that the proposed plan will double the capacity of the bridge. Traffic projections indicate that with a double deck in operation no additional vehicular crossing facilities would be needed prior to 1985.

The construction period to complete the plan from the time of awarding the first construction contract is estimated at approximately four years.

The cost of construction would require a final study with sufficient detailed plans from which quantities of materials can be obtained and priced.

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BIBLIOGRAPHY

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GENERAL OUTLINE OF FEATURES
TO BE COVERED
IN A
FEASIBILITY REPORT
ON
DESIGN AND CONSTRUCTION
OF A SECOND DECK
ON THE GOLDEN GATE BRIDGE

SCOPE OF WORK FOR STUDY

AS PROPOSED BY

GOLDEN GATE BRIDGE AND HIGHWAY DISTRICT

GENERAL OUTLINE OF FEATURES TO BE COVERED IN A FEASIBILITY REPORT ON DESIGN AND CONSTRUCTION OF A SECOND DECK ON THE GOLDEN GATE BRIDGE

(NOVEMBER 30, 1965)

A. BASIC CONCEPT OF PROPOSED DESIGN (of Tudor Engineering Company)

1. Second deck below existing roadway.
2. Roadway width between curbs 60 feet.
3. One-directional traffic on upper deck and opposite direction on lower level.
4. Minimum vertical clearance on lower deck 15 feet, 6 inches.
5. Sidewalks on each side of lower roadway with suicide prevention devices.
6. No interference with traffic flow during process of reconstruction.

B. ALTERATIONS THAT SHOULD BE DESCRIBED IN REPORT

1. Structural changes in the following major components:

    a. North and south abutments.
    b. North and south viaducts between abutments and pylons.
    c. Arch span on south end of bridge.
    d. North and south pylons and north anchorage.
    e. Main towers.

2. Structural components to be removed, and replacement or substitute members to be installed at the towers and the extent to which towers will be weakened during process of removing existing below-deck cross bracing, both under normal conditions of weather and in event of unforeseen high wind velocity.

3. Sequence of operations in detaching existing below-

deck cross bracing, removal of rivets from vertical plates on roadway side of tower legs, and placement of new reinforcing plates on inside of tower shafts.

4. Extent and nature of changes in the stress pattern of the tower, of strut no. 5, of strut no. 6, and of cross bracing between struts, that will result from modification of the below-deck cross bracing.

5. Length of time during which the load-carrying capacity of the cross bracing between struts no. 5 and no. 6 will be removed during process of alteration at each tower.

6. Maximum number of panels below deck that will be deprived of cross lateral bracing and vertical diagonal knee bracing, at any time.

7. Extent and location of modification in stiffening trusses and maximum number of panel lengths of upper and lower chords that will be detached at any time.

8. Extent and sequence of adjustment of suspender rope main cable clamps to compensate for anticipated reduction in load.

9. Method of providing interim roadway lighting, continuance of electric power transmission, instrument control circuits and communication circuits now occupying conduits in concrete sidewalks, if the sidewalks and light standards are to be removed progressively in pace with new lower deck construction.

10. In the process of removing two lanes of existing concrete roadway at a time after completion of the lower deck, what type of barrier will be provided between the remaining four useable lanes and the opening where two lanes of concrete are removed.

11. For what distance, longitudinally, will there be an opening in the two lanes from which concrete is being removed.

12. What will be provided as a pedestrian walkway on the upper deck by use of which motorists might take refuge from traffic in event of disabled vehicles, and for access to emergency call boxes.

13. What type of suicide barrier would be used, where would it be located and to what extent would it interfere with bridge maintenance workmen; what would be used to prevent suicides from the upper deck; and what provision would be made to prevent motorists on the upper deck from throwing objects that might strike pedestrians on the lower sidewalk.

14. Specifically, what type of roadway decking is contemplated for use on the new lower deck and in replacement of the concrete upper deck.

15. Plan and profile drawing of freeway connections between bridge and highway system at north and south ends.

16. Nature of alterations contemplated in roadway surface, toll collection facilities, buildings and structures at the toll plaza, including specific reference to the existing administration building, electric power substation, main shop and Round House Restaurant.

17. What system of roadway connections is contemplated through the toll plaza area, at the crossing of Lincoln Boulevard on the Presidio, and tying into the existing approach roads, with further provision for possible future improvements in the roadways through the Presidio.

18. By what method has the computation been made leading to the conclusion that five lanes above and five lanes below on the bridge, with unidirectional

traffic, will double the capacity of the bridge.

C. COLLATERAL DATA REQUIRED

1. Full explanation of all effects required to establish feasibility.

2. Perspective drawing of a section of the suspended span to show lower deck roadway as it will appear when completed.

3. Drawing of transverse section through the suspended structure with enlarged views showing pavement lateral bracing, and connection of lower deck floor beams to trusses.

4. Drawing of longitudinal section through the upper and lower decks at the towers.

5. Elevation drawing of tower showing its appearance after modification.

6. Program of construction giving sequence of principal operations and the design loads existing at critical stages, with specific detailed explanation of contention that when alteration is completed the loading will be less than original design load, as stated in presentation to Bridge District Board of Directors by Mr. Norman C. Raab.

7. Features in Tudor concept for a second deck in the handling of traffic.